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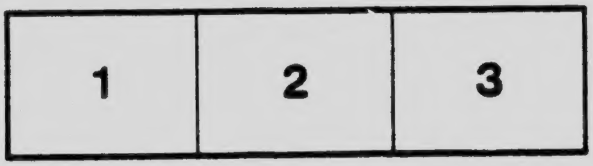

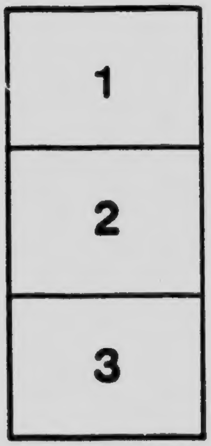

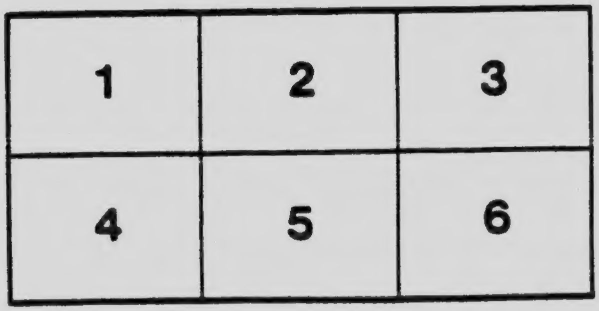

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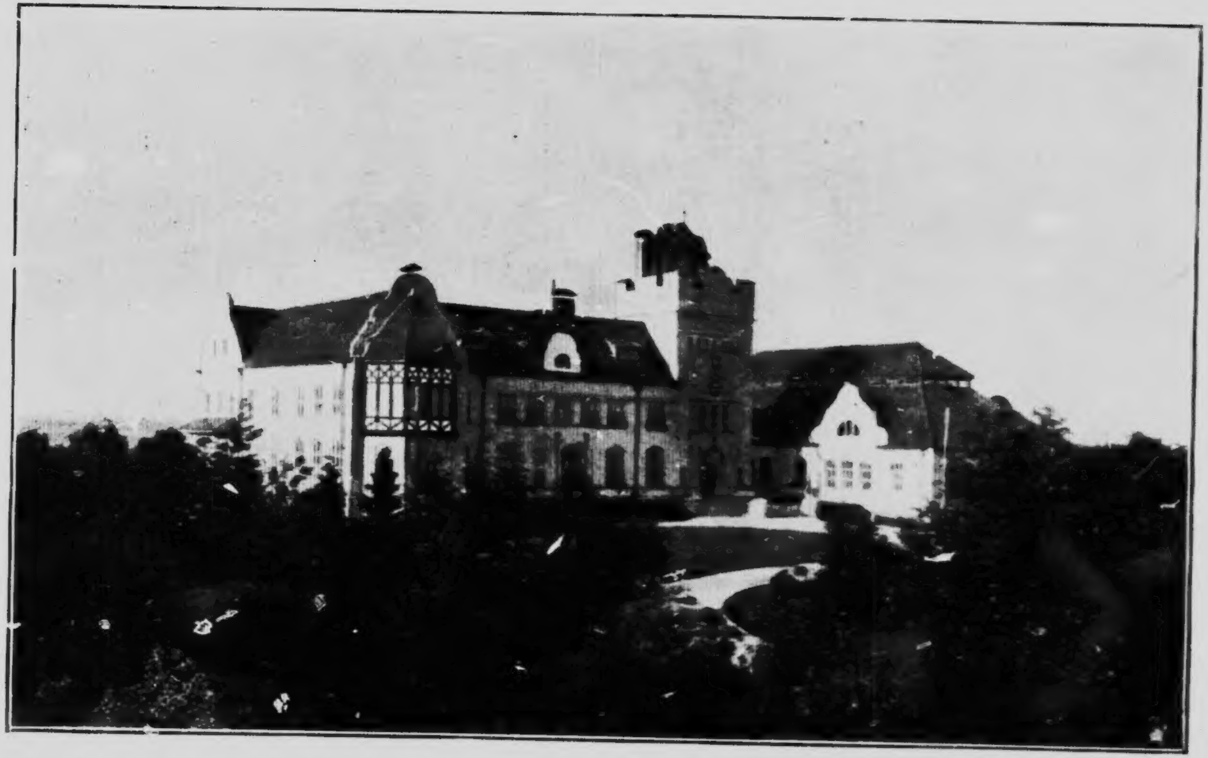

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FIG. I.—Frontispiece. Main building, Swedish Seed Association, Svalöf.

PREFACE

The material presented in this book is the result of a special enquiry made by the writer into the present status of plant-breeding in that part of Northern Europe known as Scandinavia, which comprises the three countries of Sweden, Norway and Denmark. For various reasons practically all the time available for this investigation (about nine months) was spent at the headquarters of the famous Plant Breeding Institution known as the "*Swedish Seed Association*" situated at Svalöf, a little village in the southern part of Sweden. My remarks will therefore concern very largely the work of this institution, although reference will be made from time to time to endeavors of a similar nature elsewhere.

The main object of this publication is to give a general survey of the work conducted at Svalöf from the time of its inception and to indicate some of the facts and circumstances which have led to the adoption of principles of breeding now recognized at that place. For this exposition I claim neither originality nor completeness. The facts submitted have been taken from printed or private records to which reference is made in practically all cases. The one object has been, in the words of Huxley, "to know what is true in order to do what is right."

I am also deeply sensible of the great obligation I am under to Prof. Hjalmar Nilsson, director of the Institution at Svalöf, not only for permission to investigate the work, but still more for the personal assistance and great courtesy which he at all times extended. In no less degree am I indebted to Drs. Nilsson-Ehle, Hans Tedin, Hernfrid Witte and Mr. Lundberg who, as experts in direct charge of their respective branches, were most untiring in their efforts to present their work *exactly as it is*.

While efforts have been made to render the following pages as intelligible to the general public as the nature of the subject would permit, they are addressed primarily to the scientific reader.

In order more fully to appreciate the difficulties as well as the possibilities associated with the production of more useful forms of cultivated plants in Sweden, the reader is commended to study carefully the *Appendix* in which are considered the geographical position, physiography, climate, precipitation etc., of this country.

The scientific aspects of the achievements in Sweden are of special interest by reason of the extent to which they add to our knowledge of biological problems.

L. H. Newman.

Ottawa, Canada, June 15, 1912.

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PLANT BREEDING IN SCANDINAVIA

I.—INTRODUCTION

There is no subject associated with plant life which is of greater importance yet which is less perfectly understood than that of plant improvement. Efforts to guard against the deterioration of cultivated races date back to the early Romans who, according to Virgil, recognized the need for continued care in preventing the inclusion of variations of inferior value. The idea of actually *improving* plants is of comparatively recent origin, dating probably from about the beginning of the nineteenth century. Since that time great strides have been made and it is only with difficulty that one is able to follow at all adequately, the rapid accumulation of experimental data.

While the idea of organic progression had its birth among the early Greeks and while many theories were later advanced by prominent investigators as to the "mode" by which new forms arise, yet it remained with Chas. Darwin to first develop a well supported theory of evolution which he called the "*Theory of Natural Selection.*" This theory, as is well known, assumes that a constant inherent variation is going on within the race. Some of the resulting variants will be stronger and will survive, others will be weaker and will perish in the struggle. The Darwinian principle has been widely applied in practice with a view to the improvement of cultivated varieties and not without a certain measure of success.

An enormous impulse to further investigation in the realm of biological science was given by the rediscovery and confirmation in 1900 of Mendel's famous principles of heredity (25) (first communicated to the Naturalists' Society of Brünn in 1865, but subsequently overlooked) by DeVries, Correns and Tschermak, subsequently defended and developed as they were by Bateson of England (1). The appearance in the same year of the "Mutation Theory" propounded by DeVries (78) also contributed greatly to a revival of interest in matters pertaining to the great vital problems of natural science.

The views expressed in these theories have served not only to deprive the principle of Darwinism of many of those attributes with which it had been invested but to bring about a vital change in the general conception of the whole phenomena of variation and heredity. These views, together with the degree to which they find either support or contradiction in the experiences of the leading Scandinavian investigators, will be discussed in the following pages.

In seeking support for his theory of "an origin of species by sudden 'mutations'" and in searching for evidence to show the "high practical value of elementary species which may be isolated by a single choice", De Vries has endeavored to interpret the results obtained at different institutions in the terms of his hypothesis. It was in this way that the Swedish Seed Association at Svalöf, Sweden, was first brought into prominence, especially in America, since in his book "Plant Breeding" (79) published in 1907, DeVries dealt at some length with the work being carried on at that institution. Our thanks are due Dr. DeVries for bringing this work to our attention and for suggesting new and interesting lines of thought and modes of thinking. Unfortunately, however the principles of plant improvement now actually recognized by the experts at Svalof, not being in full agreement with those described by the above author, a wrong impression regarding the work at that place has been spread abroad.

After elaborating upon the composite nature of our ordinary cultivated varieties, as demonstrated by the studies of the men in Sweden, DeVries states his point of view clearly and concisely as follows:—

"The range of variability disclosed by these new studies is simply so wide that it affords all the required material for almost all the selections desirable at present and will no doubt continue to be an inexhaustible source of improvements for a long succession of years. They are founded on the principle of single selections, and the range of application of this method is proven to be so extensive as to make all ideas of repeated or continuous selection simply superfluous. It is even so rich in its productiveness that there is scarcely any room left for other methods of improvement; and especially should all endeavors of winning ameliorated varieties of cereals by means of hybridization simply be left out of consideration, as compared with the immense number of more easily produced novelties which this method offers." (l.c. p. 50).

The inference here is clear. Our ordinary varieties are composed of a mixture of distinct types. These are so numerous as to render the production of new forms by artificial hybridization quite unnecessary. The problem of the breeder is simply to isolate and propagate the most promising forms and by a process of elimination, finally to locate the best. The discovery of these forms is supposed to be aided by the fact that certain botanical or morphological characters are indicative of or correlated with industrial qualities, thus: "Whenever a distinct quality is desired, either in order to improve a local variety, or to bring it into a form suited for other conditions of soil or climate, or to comply with any other wishes of agricultural practice, it is necessary only to know the botanical marks correlated with the desired qualities. On this basis individual plants may be singled out, and after multiplication through a few years, their progeny will probably respond to the demands made, as soon as the industrial qualities themselves are investigated." (l.c. p. 277–8).

The work at Svalöf to-day leaves little support for these conclusions. On the contrary, it clearly indicates that these early opinions were based upon insufficient evidence and incorrect interpretation. As time passed, experimental evidence has accumulated and with it have come new ideas and new modes of thinking, giving birth to new conclusions. The general position held by the men at Svalöf at the present time may therefore be summed up in brief as follows:

(a) *A progressive system of plant improvement cannot be a one-sided system but must embrace all possible methods of reaching the desired end*

(b) *Artificial hybridization provides an invaluable means of producing superior combinations of characters (sorts) which are not found in nature and this method is now used largely at Svalöf for this purpose.*

(c) *The old system of 'mass selection' can still be of value in special cases and has never been fully abandoned.*

(d) *Superior strains may often be found in a mixed variety, but since these need not necessarily possess striking botanical or morphological characters, their isolation, on the basis of such characters, cannot safely be effected.*

A careful study of the development of the work at Svalöf since its inception, is essential to a clear appreciation of the position as above expressed.

II.—THE SWEDISH SEED ASSOCIATION *(General résumé)*.

The Swedish Seed Association was established in April 1886 on the initiative of Birger Welinder, a keen, far-seeing farmer of independent means, operating a large farm near the village of Svalöf.

The aim of the Association, as indicated in the first section of its Constitution, is "to work for the cultivation and development of improved sorts of cereals and other crops and for the utilization of these sorts in Sweden and in other countries." The Association further aims:

Aim of the Association.

(a) "To ascertain the value and suitability for our conditions of both native and foreign sorts by means of carefully conducted experiments located at different places."

(b) "By means of careful breeding to seek to produce stock seed of special value and to distribute it throughout the country."

(c) "By means of exhibitions, literature and other suitable measures to spread information throughout the country and encourage the general use of good seed."

The various circumstances and conditions which operated in bringing this Association into existence are of more than passing interest. They are closely interwoven with the social, economic and even the political life of the country. They reveal an antiquated and unprogressive system of land tenure, extravagant and dangerous methods in agriculture and finally an industrial renaissance following upon a realization of the great dangers to the nation of continued disregard of the first essentials of commercial and industrial stabiiity.

While the Agriculture of Sweden is [illegible] date back to the Stone Age, modern Agriculture in that country ma [illegible], to have had its birth about

Early Swedish Agriculture.

the year 1840. From 1840 until about 1870 the growing and selling of cereal grains was the principal industry. Following 1870 an important change in Swedish Agriculture gradually took place. The long period of continuous grain raising began to show its effects in decreased fertility of the soil and as a result the grain growers found that they must change their system and feed their produce at home in order to return to the land at least a portion of the fertility removed by the crops.

Another important circumstance which contributed to the bringing about of a change in method was the great decrease in grain prices, following the extensive importations into Europe of American cereals. The Swedes found that they could not produce grain as cheaply as could the growers of North America, and despite the great difference in distance between the two continents, competition practically forced them to find some other means of disposing of their products.

E[illegible] of Schübeler.

During the period of large grain exportation, and even later, Dr. F. C. Schübeler (63; 64; 65, p. 145-9), Professor of Botany in Christiania University, Norway, had been conducting very extensive investigations into the effects of a northern latitude and climate upon plant life. He showed that such conditions conduced to produce seed of greater weight, better quality and of earlier maturity due largely to the increased number of hours of sunlight enjoyed by the plants in this northern country during the growing period. He believed, moreover, that the qualities which were thus acquired were hereditary and as a consequence when seeds grown in the north were sown in southern countries that they would continue to produce plants bearing the same rich, early developing, heavy seed indefinitely. Schübeler's publications on this question created much interest among the people of Sweden who imagined that nature had thus provided them with a new source of wealth in making possible the establishing of a lucrative trade in grain for seeding purposes with Germany, Belgium, and other countries not so favored. Many trial samples of seed were sent into these countries for testing, but the results were rather disappointing due largely, it is believed, to the fact that the sorts sent were quite impure, and consequently produced a mixed and unsatisfactory crop. As will be seen later 'earliness' is not essentially the product of a northern position, although such a position seems to have decided influence on the weight and quality of seed.

With a view to encouraging the cultivation of a better class of seed grain, several local associations were organized in the early eighties and many continental sorts of wheat, oats and barley were imported into Sweden for trial. It was hoped that better sorts than those then growing in the country would be obtained and by careful growing under control and under the beneficial climate of Sweden for a few years it would be possible to offer the Southern trade a quality of seed for which a handsome price would readily be paid. These associations never had more than a local influence and, as a consequence, the period of their activities was of short duration.

During this time Birger Welinder, to whom reference has already been made, had watched the progress of affairs and had studied the situation closely. He believed that the impurity of Swedish sorts had been chiefly to blame for their indifferent success in foreign lands and so conceived the idea of producing seed of *pure and constant sorts* by a process of continuous selection, crossing and other scientific means, and of making this seed available in quantity to the farmers of his native land. In this way it was hoped that a more rational system of seed production would be developed at home and that eventually there would take place a substantial export of improved Swedish seed to other countries. His ideas seemed logical and were readily and quite widely accepted. The question became a national one and much interest was evinced.

Ably supported by another public spirited gentleman in the person of Baron Gyllenkrook, a large landed proprietor in the neighbourhood, Mr. Welinder proceeded to interest others in the work until soon a noble band of earnest-minded men gathered together and organized on April 13, 1886, the South Swedish Association for the cultivation and improvement of seeds, with Baron Gyllenkrook as President and Mr. Welinder, as Secretary. At first this Association was intended to affect only the southern part of Sweden, but soon it was seen to be too popular to suffer such restriction and its name was accordingly changed on November 30, 1887, to the "General Swedish Seed Association" with a correspondingly increased scope.

In 1889, another Association (Central Swedish Seed Association) was organized independently at Örebro in middle Sweden,*) to serve the needs of that part of the country, it being thought that an organization so far south as that at Svalöf could not do justice to the whole land. In 1894 this Association handed over its work to the southern association with the understanding that the latter would extend its activities so as to meet the needs of the central districts. The Association at Svalöf now had a clear field and again changed its name to the *Swedish Seed Association* which name it still holds.

Membership.

The membership of the Association is composed of honorary members, life members and annual members. The fee for annual membership is five kronor ($1.35). All members receive the Association's Journal (*Sveriges Utsädesförenings Tidskrift*) which is now published, as a rule, every second month, and such other publications as are occasionally edited. In addition to this, the Association assists members in various ways, such as by giving advice on questions pertaining to crop-raising, etc. No actual work is required of members since practically all breeding and selection work is done on the grounds of the Association, either at the headquarters at Svalöf or at the Branch Stations.

The affairs of the Association are administered by the following officers:—

Administration.

(a) *An Executive Council* (Mindre Styrelse) consisting of not less than seven and not more than twelve members and three vice-members.

(b) *A Board of Directors* (Större Styrelse) consisting of the honorary members of the Association, all the members of the Executive Council and a representative from each Agricultural Society which contributes towards the Association. Those societies which contribute more than 500 kronor can elect one representative for each 500 kronor contributed.

---

* By "Middle Sweden," as used in this paper, is meant that part of Sweden lying between parallels of latitudes 58 and 60.

Branch Stations.

In addition to the main Institution at Svalöf, the Association has two Branches, one for Central Sweden at Ultuna, north of Stockholm, which works in co-operation with the Agricultural College located at that place, and one for the far North at Luleå where the work is executed in co-operation with the Institution for Chemistry and Plant Biology. The need for more branch stations has long been felt and it is expected that the present number will be augmented in the near future.

Funds.

The revenue of the Association is derived from membership fees, government grants, county grants, contributions from the Agricultural Societies, fees from the Swedish Seed Company on account of stock seed sold the said company and for the inspection and control by the Association of the commercial product. In addition to the above the Association occasionally receives substantial donations from private parties, companies and Associations which are interested in the work.

Experimental Grounds.

The Association possesses at Svalöf about 16 hectares (39½ acres) of land on which are established its buildings, residences and outhouses. The additional land which may be required for experimental purposes is leased from the *General Swedish Seed Company*, which owns about 3,000 acres adjoining the Association's grounds.

III.—THE SYSTEM OF PLANT IMPROVEMENT AT SVALÖF AND ITS DEVELOPMENT.

The Method first Employed

When the Association at Svalöf first began its work of plant improvement it adopted the system commonly followed in Europe at that time. This was known as the *System of continuous or systematic selection*, the aim of which was, by selection from year to year, to shift the type in its entirety in a certain desired direction. This principle assumed the omnipresence of hereditary variations and, in accordance with the Darwinian idea, it was believed that permanent and substantial improvement might be effected by selecting plants which varied in the direction wished for. In other words, it was thought that continuous selection produced a *cumulative* or *creative* effect.

The above principle was usually applied in practice through what was known as the system of "Mass Selection." By this system, a selection of seed was made from a large number of plants and the whole thrown together and sown "en masse" in a single plot.

When a sort, by reason of the results of careful testing or for other causes, was chosen for improvement there were taken from the threshed sample from 1,000 to 2,000 kernels for planting in a special plot. The "grading machine" (consisting of a series of sieves) made a discrimination in the size of the kernel, while the "Diaphanoskop" was sometimes used in judging the quality of the sample that should be planted. These kernels were then sown out at definite distances apart by means of the so-called "marker" which consisted of boards fastened together to make a panel about 1.50 m. (59″) long by about 0.50 m. (19½″) wide. This was pierced with holes about ¾″ in diameter arranged in rows placed 10 c.m. (4″) apart while the holes in each row were 7 c.m. (2.7″) apart. These distances were changed in later years to 15 c.m. (5.9″) and 5 c.m. (2″) respectively. By thrusting a steel punch (Stämpel) through the openings in the board, holes of a certain depth were made in the soil, into each of which a single seed was dropped. By this method not only were the resulting plants allowed to develop evenly, but a study of single plants was facilitated. The adoption of this method of planting having for its aim the reproduction of normal conditions, marked a radical departure from that commonly used by Hallet, Rimpau and many other breeders at that time who planted very thinly, thus allowing an abnormal development. A second departure from the common rule was made in the choice of location for the special plots. Contrary to the custom of the above mentioned breeders who continually sought for locations having extreme fertility, the Svalöf practice was to use only fields which were *normally* rich and which were in proper place in the rotation.

The Swedish system, which was regulated and controlled by a most exacting mechanical system prosecuted in the laboratory, gradually attained a high state of development under the direction of Th. Von Neergaard, a German mathematician and chemist, who had been appointed leader of the work shortly after the Association was organized. Neergaard had a wonderfully keen, mathematical mind and during his regime some ingenious instruments were devised and a fine system of measuring, weighing and recording both plants and seed was employed. The aim at this time was to exclude the personal element as far as possible and to accept as far as circumstances would permit, the mechanical evidences of superiority.

The first choice of plants was made in the field, the rule being to select only plants which were uniform in length of straw and in general development. Care was also taken to select only those plants which did not produce more than three stalks per plant, the idea being that such plants were likely to develop more evenly, to yield better and to give a product of better quality. Experience soon showed however, that the degree of stooling could not be taken as a sure indication of the value of a sort; it was only suggestive.

The plants which were chosen from the "élites" were pulled up by the roots, taken to the building and subjected to the searching mechanical examination to which we have already alluded. On the basis of this examination the final choice of seed for new "élites" was made.

Early Laboratory Studies.

A closer study of the characters which this laboratory examination took into consideration is interesting. In the first place a selection had to be made of the plants brought from the fields. This choice was based on the average quality and yield of grain per plant, together with the nature of certain botanical characters which were believed to characterize certain groups or types.

A discrimination was next made between the heads or panicles of the chosen plants. Only heads or panicles from the main stems of each plant were taken as it was believed that such heads or panicles offered greater possibilities than did those borne on the lateral and usually less perfectly developed shoots or "stolons."

The chosen heads were then weighed, it being believed that the heavier the head the larger the kernel and the greater the yield. When the heavy heads had been selected, the next step was to choose those which contained the greatest number of spikelets as it was thought that this was directly correlated with yield. Since long open heads of wheat, barley or rye often produce actually fewer spikelets than the short more compact type and since the latter type was thought to be correlated with stiffness of straw a system by which the *specific density* of a head, or the number of nodes per 100 m.m. (3.9″) could be expressed, was devised. By this system, the density of the different heads could be expressed in figures and another important basis of selection thus established. The manner in which this system was applied may be explained more clearly by setting the following problem thus:—

A head of wheat measuring 130 m.m. in length has 24 nodes containing 70 kernels. Problem: What is the density (number of nodes in 100 m.m.) of this head and the number of kernels per 100 m.m.?

Answer:—

In 130 m.m. there are 24 nodes

" 100 " " $\frac{24}{130}$ x 100 = 18 nodes. Specific density = 18

(This was commonly expressed as "D. 18").

In 130 m.m. there are 70 kernels

" 100 " " $\frac{70}{130}$ x 100 54 kernels.

In order that the density of a large number of heads might be quickly determined, Neergaard devised the first *automatic classificator* used at Svalöf. This obviated the necessity of working each case out on paper as above.

The choice of heads having been effected, the next step was to choose the best kernels. In accordance with the old idea that these were to be found near the centre of the head in wheat, barley and rye, and in the upper part of the panicle in oats, only kernels from these places were taken for seeding.

The use of sound, plump and large sized kernels for the sort was insisted upon. The importance of this practice has never been challenged.

A further selection of kernels was sometimes made on the basis of quality, an expression of which was sought by means of the "Diaphanoskop," an instrument which made it possible to compare the "mealiness" of different kernels by placing them over openings through which the light might pass according to the transparency of the kernel. A hard, glassy and therefore more transparent kernel in wheat was considered of better quality than a mealy, opaque kernel, while in barley the latter type of kernel was believed to be more suitable for the brewer.

Final valuation of sorts.

The final valuation of a sort must naturally depend largely upon field trials and a laboratory analysis of the product. Such trials and analyses have occupied a prominent place at Svalöf from the beginning and will be discussed more in detail later.

Results from Continuous Mass-Selection.

Efforts to develop a strong strawed type of Chevalier Barley by mass-selection.

During the first period in the development of the work, efforts were naturally directed toward the alleviation of the most pressing needs of the farmers. Among these needs was that for a Chevalier barley with a stiffer straw. This sort was considered at the time to be without an equal in quality for brewing purposes but had the one serious defect of lodging under comparatively slight provocation. Repeated selections were therefore made of those plants which possessed heads of the greatest density in accordance with the prevailing idea that a definite relation existed between density of head and strength of straw. All attempts in this direction however proved futile and were finally abandoned. This failure is attributed to the fact that the Chevalier in question was a pedigree sort produced by Hallet of England and as such, possessed a degree of constancy which precluded the possibility of effecting improvements by means of the system practised. On the other hand, had this sort actually been a common mixed variety it is doubtful if any progress in the desired direction would have been made since it has been shown that no absolute relation exists between compactness of head and strength of straw. Thus the failure to produce a stiff strawed Chevalier by continuous mass-selection cannot be accepted as an evidence of defects peculiar to this system alone although DeVries has regarded it as such (79 p. 64).

Development of Clay and Moss barley.

Other selections of heads of varying specific densities were made from the Native Plumage barley. "This variety," says Bolin, "was found to contain 10 to 12 different classes in regard to density of head while the different plants showed corresponding differences in manner of growth and structure of straw" (5 p. 60). Thus in 1888 approximately 1000 heads were selected and divided into two main groups representing the two extremes of density while a third group represented the average density of the whole number (See Fig. 2). In the group containing the most open heads the density averaged from 40 to 41 and the seed of this group was taken to plant plot XII_I in the Spring of 1889. In the group containing the most compact heads the density averaged from 45 to 48. The seed from this group sowed plot XII_{III} in 1889. The group representing the average condition of the whole 1000 heads in regard to compactness averaged 42 to 44. This group sowed plot XII_{II}. An examination of the table will indicate the performance of each group in succeeding generations and will reveal the interesting fact that from the group possessing the most open heads in the beginning there was ultimately produced a sort (0501) which remained relatively lax, while the group possessing the average density of the whole 1000 original heads was found at the end of three years to have an average density identical with that of the most densely headed group. From the progeny of the latter group a sort (0502) was produced which had a denser head, ripened about 10 days earlier and produced a lower yield than 0501. It also possessed a peculiar dark grey color of stem and leaf. Both 0501 and 0502, which received the name *Clay* and *Moss* respectively, belonged to the Erectum type although the former possessed a decidedly nodding (Nutans) head. This is a good example of a sort with a nodding head actually belonging to the Erectum group and indicates clearly why the position of the head cannot be taken into consideration in a system of classification (See classification of barley types page 133).

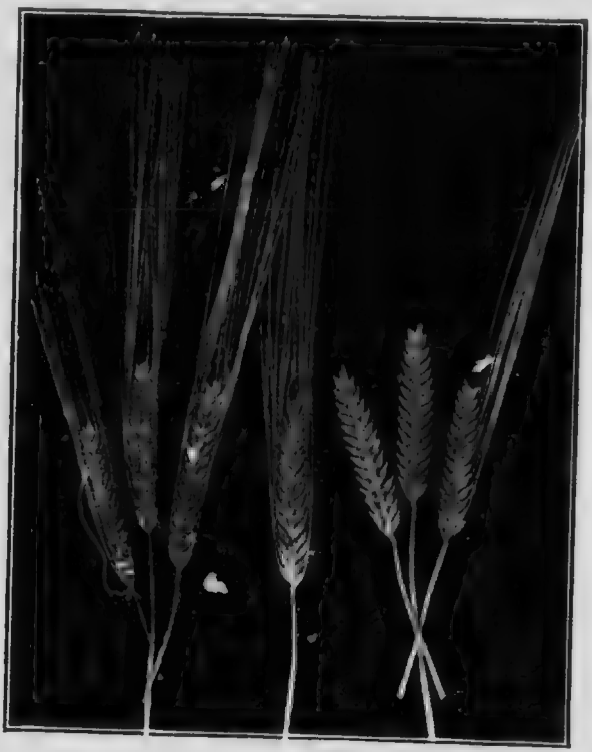

Photo by Courtesy S. S. Ass'n

Clay *Moss*

FIG. II.—Two Mass-Selected Barley Sorts.

Origin	1888	1889	1890	1891	1892
Swedish Plumage barley 1887—from Alnarp.	Plot No. XII (about 1000 plants)	Plot No. XII^{I} D = 40–41	Plot No. 12_1 D = 37–39	Plot No. 11. D = 43-45	Plot No. 11. D = 41–43, *Clay* (0501)
				12. D = 43–45	
		XII^{II} D = 42–44	12_2 D = 39–42	13. D = 48–50	12. D = 44–46, *Moss*, (0502)
				14. D = 48 50	
		XII^{III} D = 45–48	12_3 D = 41–42	15. D = 48–50	
				16. D = 48–50	

FIG. III.—PEDIGREE OF CLAY AND MOSS BARLEYS.

The development, or more properly the *separation* of the above two barley types affords an excellent illustration of how selection *en masse* may be effected. The only necessary condition in order that such separation may be made is that different hereditary forms be present and that these present differences in respect of the character sought. In the case in question this success was due to the existence of different forms possessing different specific head-densities. By the annual selection from each group of those heads, the density of which approached most nearly that which was desired, there was gradually eliminated the 'transgressive' or 'overlapping' forms until at the end of the fourth year two groups representing the two types mentioned remained.

This explanation of the separation of the two barley sorts *Clay* and *Moss*, affords an argument that at least some of our common varieties are composite in character and are capable of being divided into their component parts which in turn may possess different values.

A similar example of how it may be possible to effect gradually a separation of two distinct types by mass-selection is to be found in an experiment conducted some years ago at the Experimental Station at Tystofte, Denmark. scribed by Tedin (66 p. 23) in the journal of the Swedish Association. rimary object of this experiment was to determine the comparative s for seeding purposes, of large and small kernels in the case of barley and oats. Both the large kernelled lot and the small kernelled lot required for this experiment were obtained from a mixed variety, and in each succeeding generation the sample of large kernels required to continue the test was obtained from the plot sown with large kernels while the small kernels were obtained from the plot produced from small kernels. This practice was continued for a number of years with the result that, to the surprise of those interested, two apparently quite distinct types were finally separated.

The inference in this case must also be that the original varieties were composed of different strains, some of which were normally small kernelled and some large. By continuously taking only the small or large kernels, as the case might be, from their respective groups, all transgressive forms in respect of the character concerned, were gradually eliminated, with the above result.

The principal object of the work at this time being to produce "pure, constant and uniform sorts," great care was exercised in selecting plants which corresponded as closely as possible with a given type. Due attention was therefore given to all botanical marks which might aid in this direction. Thus in seeking to produce pure stocks of barley, certain marks on the kernels were found of assistance. With the help of these marks, which proved to be the basis of the present system of classification for barleys in use at Svalöf and which will be described later (See page 133), a relatively pure stock of two old sorts (*Chevalier* and *Prentice*) was produced and placed on the market in the early nineties (29, p. 10). Relatively pure stocks of other sorts such as *Swedish Plumage* barley and *Black Tartarian* oats, soon followed, while in 1895 a stock of improved Prentice barley which received the name *Princess*, another of *Awnless Probstier* oats and still another of *Renodlad* (Selected) *Squarehead* wheat, were given over to the General Swedish Seed Company for propagation and distribution. The development of the three last sorts is interesting.

Development of the original Princess Barley.

In the case of *Princess*, Bolin (6, p. 113-14) isolated three groups of forms from the old Prentice variety of barley, each of which groups possessed certain prominent characters. The most prominent characteristic of one of these groups was said to be the peculiar arrangement of the lateral rudimentary kernels which, on one side of the head near the tip, assumed an almost upright position. From this group was obtained the original *Princess* barley a stock of which was given over to the General Swedish Seed Company in each of two years (1895-1896) and which quite displaced the old Prentice.

The superiority of the new sort over the old is said to have been in its striking uniformity in height and color of plant and in its higher yield. For the average of the four years 1894-97 it gave decidedly higher yields than Prentice which came next among all sorts tested (30, p. 136).

A pedigree sort out of Prentice displaced the mass-selected sort Princess about 1897 on account of the belief that pedigree sorts must be better than composite races. The results do not show however, that pedigree stocks out of the variety mentioned, actually excelled Princess in yield.

Origin of Awnless Probstier Oats.

The first attempts to develop an awnless strain of oats were made soon after the organization of the Association, the common Probstier variety being chosen as foundation material. The presence of awns was regarded as not only detracting from the appearance of a sample but also preventing the grains from packing closely in the measure, thus reducing the weight per bushel. The first efforts in this direction led to no results when finally, after several different courses had been tried, it was decided to reject all plants which had the slightest appearance of an awn on any of the kernels and which were not sound and entire with not a single kernel missing. These later attempts proved successful in producing an awnless sort which received the name '*Awnless Probstier.*' This sort showed not only greater uniformity than the old sort, but also during the years 1893-96, when the two sorts were competing in the comparative trials, it gave a little higher average yield (33, p. 178). For these reasons it soon came to practically displace the old sort and, even to-day, stands among the highest yielders in Sweden.

Origin of Selected Squarehead Wheat.

Renodlad (Selected) *Squarehead* wheat was produced by mass-selection after the severe winter of 1891, when a selection was made of the best of those plants which had survived (See Fig. 4). A quantity of this stock was given over to the Seed Company in 1895, since which date several renewals have been made from selections following such severe winters as 1899 and 1901. By these repeated selections the proportion of hardier Squarehead individuals within this variety, according to Nilsson-Ehle's reports (39, p. 272; 51, p. 73) has gradually increased until now this is among the most hardy of the high yielding sorts. Indeed up to the present, no sort has been found more suitable for certain large districts in Sweden. In yielding tests at Ultuna, since 1904, it has given the highest average yield of any disseminated sort originated by the Association.

The efforts to effect improvements upon certain old varieties of cereals by the system of mass-selection as applied at Svalöf were therefore by no means without results. Greater uniformity, higher yielding capacity and, in autumn wheats, greater hardiness were the ultimate rewards of these endeavors, although it required several years before the extent of this improvement became fully demonstrated.

Introduction of the Pedigree Culture system of Selection at Svalöf.

Prof. Hjalmar Nilsson appointed director.

After the Association had been in operation for about five years Prof. Hjalmar Nilsson succeeded Von Neergaard as director. As first assistant to Neergaard, Nilsson had closely followed the progress of the work and had made many valuable observations. He had carefully studied the different cultures in the field and had noted the regularity with which many different botanical types appeared from year to year. In assuming the leadership he at once set to work to separate out with extreme care all plants which were botanically or morphologically different in the slightest degree. Thus during the harvest of 1891 a large number of heads from many different varieties of autumn wheats were collected as were also plants of vetches and pease. These were subjected to a most critical examination in the laboratory where several hundred apparently distinct types (200 of wheat and about 1,200 of vetches and pease) were sorted out, described and numbered. In many cases each of these types or groups was made up of many individuals. In a number of cases, however, certain forms were found which had no duplicates. Each of such forms was therefore required to represent a group in itself. Each group was now allotted a separate plot, careful records being kept of the character and number of individual heads or plants as the case might be, which comprised the progenitors of each culture.

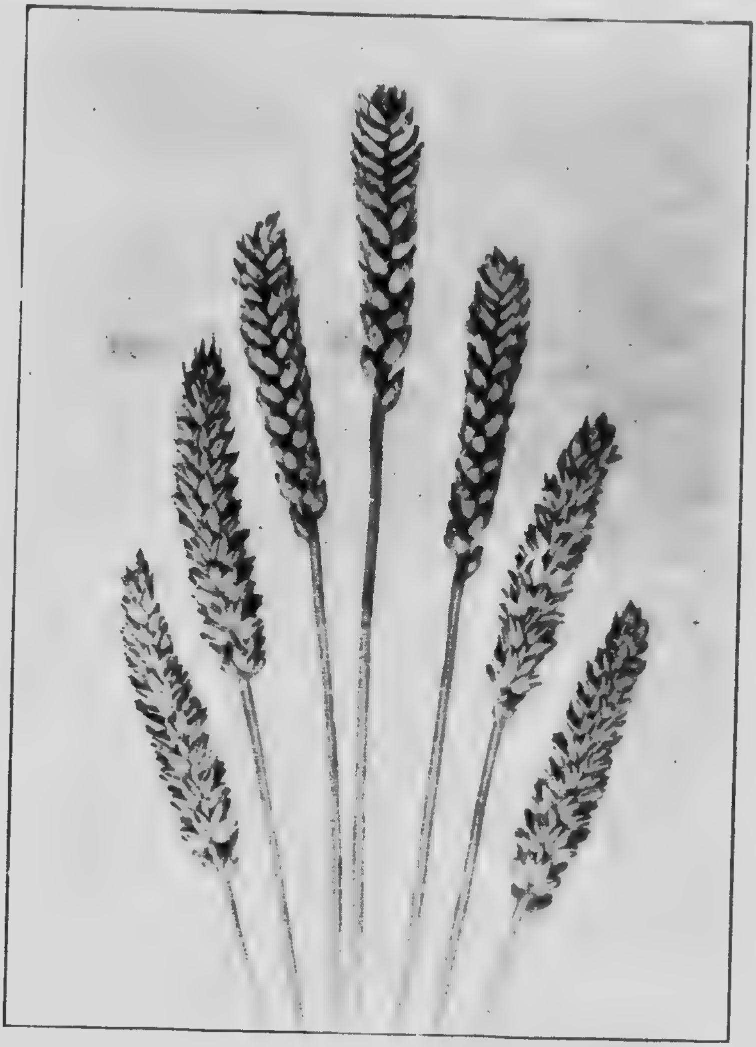

Photo by courtesy S. S. Ass'n.

Fig. IV.—Svalöf's Selected (Renodlad) Squarehead Wheat. (Mass-Selected Sort.)

A careful study of the resulting harvest did not at first suggest any solution to the problem when by mere accident an observation was made which served to place the whole question in an entirely new light. Of all the hundreds of cultures under consideration only those few which came from a single head or plant produced a uniform progeny. This observation seemed to indicate without question, that the *quickest way, if not the only way, to obtain a uniform sort was to begin with a single plant.* It was therefore decided, after the corroborating results of another year's investigations had been obtained, that henceforth all work must be based on this principle, the single plant to be the unit for improvement instead of the 'group.' This method had already been used by Vilmorin of France and is now popularly known throughout Europe as the '*Vilmorin System of Selection,*' although at Svalof it is usually referred to as the *System of Pedigree or Separate Culture.*

Form Separation on the basis of correlations.

The basic principle of the new system was to separate out the greatest possible number of *distinct botanical forms,* to propagate each of these separately and, by a process of elimination, finally to isolate the best. This idea of *form-separation* ("Formentrennung"*) as a means of discovering superior individuals as starting points for new races, had been applied by LeCouteur and Patrick Shirriff of England many years before, but at Svalöf it was introduced on a much greater scale.

While the system of separate culture was therefore not new, yet the credit of devising a new method of application was claimed by Svalöf. This method consisted of basing the selection of mother plants upon assumed 'correlations' between botanical characters and industrial qualities. Great weight was attached to such points as the position of the branches in oat panicles, the number of kernels in the spikelets and the density or closeness of the head in wheat and barley (34 p. 50). The question of correlations will be dealt with more in detail later (See page 31).

Classification of Forms into Groups.

In order to facilitate the handling of large numbers of distinct botanical forms a system of classification was devised by which it was sought to arrange the different types into sharply defined groups Thus in wheats 7 types were distinguished chiefly on the basis of the shape and density of the head; in oats 5 main types were described while in barley 12 types were named.

System of numbering the different sorts.

A system of numbering the different sorts was also devised which would indicate at once the general type to which each belonged. Thus an oat sort belonging to type 3 was given a number preceded by the figure (3). This in turn was preceded by (o) to distinguish it from ordinary numbers. *Victory* oats for example, is registered under the number 0355, which indicates that this sort belongs to type 3. The figures (55) indicate the number of the individual sort itself. This system was of great assistance so long as selection was confined to botanically different forms but when the practice later became to select large numbers of individuals from certain old races without special regard to botanical or morphological characters it naturally played a less important part.

*Fruwirth.

Pedigrees still selected from pedigrees.

With the introduction of the pedigree culture system there did not follow immediately a rejection of the original principle of continuous selection. The new system was regarded useful only as a means of obtaining in the shortest possible time, constant and uniform sorts. The Darwinian idea of the omnipresence of hereditary variation in all life was still held by Nilsson who regarded it necessary to continue the selection from generation to generation in order to effect a complete *fixation* of the characters, while at the same time he believed that continuous selection was still capable of effecting improvements even upon sorts already fixed (32, p. 13). This idea came to be abandoned in due time when it was discovered, as we shall see later, that the variations which were often noticed in these small plots were mere modifications, induced by abnormalities in such external factors as soil, moisture, etc., and that these were not hereditary.

Absence of hereditary variations in pedigree cultures.

The appearance in 1900 of the views expressed by Mendel and DeVries, together with those communicated in 1903 by Johannsen (14), the noted Danish investigator, served to place the whole phenomenon of variation in an entirely new light and seemed to explain at once, in a most convincing and logical manner, the main circumstances upon which the occurrence of hereditary variations depends. The principle involved in these views is that a plant or animal is composed of distinct and independent *Unit Characters*, units because they are capable of being treated as such. These units were regarded by Bateson as corresponding, in a sense, with atoms in chemistry. While their nature is still a subject for speculation, this author (2 p. 266) suggests that the operations of some units may be carried out by the formation of definite substances acting as ferments. By the recombination of unit characters through hybridization new 'compounds' or combinations may be effected which may appear and act quite differently. The characters entering into such a combination, however, are not themselves affected, but may be separated and recombined by future crossing to form other combinations equally distinct in character.

Theory of unit-characters.

If this theory of the unit constitution of individuals be correct then hereditary variations must obviously arise either directly as spontaneous changes ("mutations") or as the result of the combination and subsequent segregation of unit characters *through hybridization.*

Johannsen's pure-line theory.

In his classical researches in connection with problems in heredity, inspired as they were largely by the work of Vilmorin of Paris, Johannsen showed the scientific necessity of working with what he termed *pure-lines* when seeking to establish first principles. By a *pure line* he means the progeny of a single, *self-fertilizing* individual. His investigations served further to modify previous conceptions of heredity as expressed in Galton's "Law of ancestral heredity." Galton (13) worked with "crowds" or populations of individuals and annunciated that the general type of a given crowd can be changed or "shifted" by the selection of variations of a specific character (plus or minus variants). Johannsen's investigations were conducted with pure lines, that is the progeny of single individuals *within* a crowd. The plants chosen were beans and barley, both of which are normally self-fertilized and therefore easy to keep pure. The constituents of all pure lines worked with showed normal fluctuations which grouped themselves around the *mean* in accordance with the "Law of Quetelet." Certain of those constituents which deviated farthest from the *mean* in regard to certain characters, were selected and propagated separately but instead of producing a progeny identically similar to the mother plant in each case, they showed a regression to the original type of the line. Extensive experiments finally induced Johannsen to conclude that continuous selection within pure lines is unable to produce permanent changes. In other words, he concluded that there is no hereditary variation within pure lines, and therefore no possibility of effecting permanent improvements in a self-fertilizing race by means of such variation. He did succeed, however, in isolating an occasional product of what he regarded as a "mutation" or sudden variation which appeared as something "new." Should such fortuitous germinal variations arise frequently it would seem possible to obtain results by careful continuous selection along definite lines Since however, such variation might be extremely small and neither meristic nor morphological in character, it would be extremely difficult to determine whether or not any definite progress was being made. Only the best statistical methods would suffice and even then the opportunities for experimental error would be such as to render it almost impossible, except perhaps over a long series of years, to form any conclusion which would be above scientific criticism. Up to the present all efforts put forth in Scandinavia have failed to show the utility of continuous selection as a means of effecting improvements of a permanent nature in pure lines.

Johannsen's work has contributed greatly to our knowledge of selection by revealing the existence of pure lines, biotypes or "genotypes" as he sometimes calls them. He has demonstrated that continuous progress need not be expected by basing selection upon Galton's Law since a population, consisting as its name implies, of biotypes of different *means* cannot possess a biological mean. The so-called variations of Galton and Darwin, in so far as these concerned self-fertilizing plants, would therefore seem to be simply distinct biotypes which, on being propagated separately, breed true. By avoiding accidental crossing, which even in the so-called "self-fertilizing species" is known to occasionally take place, the constancy of these lines may be fully maintained. These conclusions received much support from the work at Svalöf, at which place experience seemed to show more and more conclusively that if hereditary variations did exist in pure lines they were rarely to be found, at least by mere plant inspection.

Many interesting examples are on record at Svalöf of efforts being put forth to find within these pure cultures, the starting points for new and better sorts. Thus, many apparently aberrant individuals were taken out and propagated separately, but in all cases they proved to be mere transient modifications as they failed to reproduce the special characters for which they were selected. In 1900, according to Nilsson-Ehle, an aberrant oat plant which seemed to give promise of marking an advance over its host, was found growing in a certain pedigree culture having the stock-book number *0385*. This plant had three kernels in each spikelet, while the sort *0385* was characterized by two. The kernels were described in the records as "*actually appearin* [illegible]*, more oval, plump and of better quality.*" The above plant was selected and its seeds sown the following year when the progeny still seemed promising. In 1902, seed from the preceding year's crop was sown on a larger plot when not a single "three-kernelled" plant was to be found and the attempt was therefore abandoned.

In 1900 an oat plant possessing a particularly stiff upright panicle was found in a sort (No. 0955) having a panicle which was weak, drooping and presumably of quite an inferior type. This stiff-panicled individual was selected and its seed sown in a small pedigree plot in 1901, but instead of producing all stiff-panicled plants it produced a weak-panicled progeny of quite the same type as the parent sort.

Individual winter wheat plants which survived certain unfavorable winters and springs to a marked degree, have been selected from pedigree cultures which, as a whole, had suffered more or less severely. On propagation it has been found that these do not mark any permanent improvement in hardiness over the mother sort. They have thrived under adverse conditions simply because of influences which were purely external (35 p. 176). In composite races (mixed varieties) the case is naturally different as here there may be found a 'collection' of distinct strains some of which may be normally hardier than others. In such cases the fittest will survive and in this way render the variety more hardy.

Many other examples might be cited to show the apparent futility of seeking to find at least within the first generation pedigree plots of normally self-fertilizing species, individual plants which are capable of producing better progeny than others within the same plot, but probably those aleady given will suffice. It should be noted in passing however, that repeated selections from larger cultures even of pedigree sorts are still made in the case of wheat, but such selection is not based upon the Darwinian idea of variation as we shall see later.

Necessity of working with an extensive material.

Following the discovery of the composite nature of common varieties and the consequent introduction of the pedigree culture system, it was soon seen that a very extensive material must be worked with in order that the chances of isolating superior individuals might be as great as possible. There were therefore collected hundreds of apparently distinct botanical forms, each of which was sown on a separate plot. In making this collection of forms little attention was paid at first to the standing of the variety in which they were found. Samples of seed were also collected at exhibitions and by correspondence with interested farmers and others while members of the staff took advantage of journeys into the country to collect promising looking plants from fields.

Early ideas re artificial hybridization

As a means of increasing the tendency to the production of "new spontaneous variations" (34 p. 56) according to the old idea as expressed by Nägeli, artificial crossing was introduced about 1893. In the absence of any guiding principle such as is now available, this work did not occupy an important place but was regarded as of quite secondary consideration and almost wholly of theoretical interest. Indeed it was believed that the old races contained a sufficiently rich material to meet practically all demands.

Restoration of the personal element in breeding work.

The new method being based on the isolation and separate culture of distinct botanical forms there was necessitated a most careful study of these throughout their entire life history. This fact served to restore the personal element which the mechanical system had sought in vain to displace. The various classificators, automatic weighing machines and other mechanical devices to which so much importance had formerly been attached were largely dispensed with. The importance of specialization being more fully recognized, additional experts were employed and allotted certain crops as their specialty. All their attention and study was to be devoted to the improvement of those crops for the success of which they were made responsible. Dr. Hans Tedin was engaged in 1891 as specialist for peas and vetches. Mr. Phr. Bolin was allotted the barleys in 1892*, while Prof. Nilsson himself kept wheat and oats as his specialty until 1900 when, on account of the time required to attend to the duties of a large and growing institution, this work was handed over in its entirety to Dr. H. Nilsson-Ehle who has continued it since that time. Rye was added to the list later with Mr. J. N. Walldén as specialist. This gentleman subsequently resigned and was succeeded by Mr. Erik Ljung, who occupies the position at the present time. More recently (1904) potato breeding has been taken up with Mr. J. F. Lundberg as specialist. In 1905 grasses and clovers were added to the list, Dr. Hernfrid Witte being appointed head of this department in 1907. About 1909 work in the breeding of field roots was initiated with Mr. Ivar Karlsson in charge.

Specialization of the work.

Correlation or the Association of Characters.

With the introduction of the new system each specialist set to work to study his plants thoroughly. All botanical and morphological characters, down to the minutest detail, were investigated and elaborate annotations were made and arranged in order. If certain visible characters were indicative of industrial value as was then supposed, it was obviously the first concern of the breeder to determine such and to use the knowledge so acquired in the isolation of new mother plants. The degree of constancy displayed by the various pure cultures in respect of the development of these characters seemed to indicate clearly that the latter must offer a reliable basis of distinction. Such an assumption seemed natural and logical and served moreover to make the way appear clear and relatively simple.

Relation between position of branches in oat panicle and yield.

As time passed many interesting conclusions came to be drawn as to the relationship which was believed to exist between certain external characters and industrial qualities. A few instances may here be given. In oats different 'pure lines' or strains may often be distinguished by the character of the panicle. In those forms having spreading panicles four main types may be defined thus: (1) Stiff, upright panicle; (2) Panicle pyramid-like with long, slender weakly rising branches; (3) Widely spreading panicle and (4) Panicle with branches weak and drooping (See Figs. 5 and 6). In addition to these four branching types, the common side-oat type, originally classified

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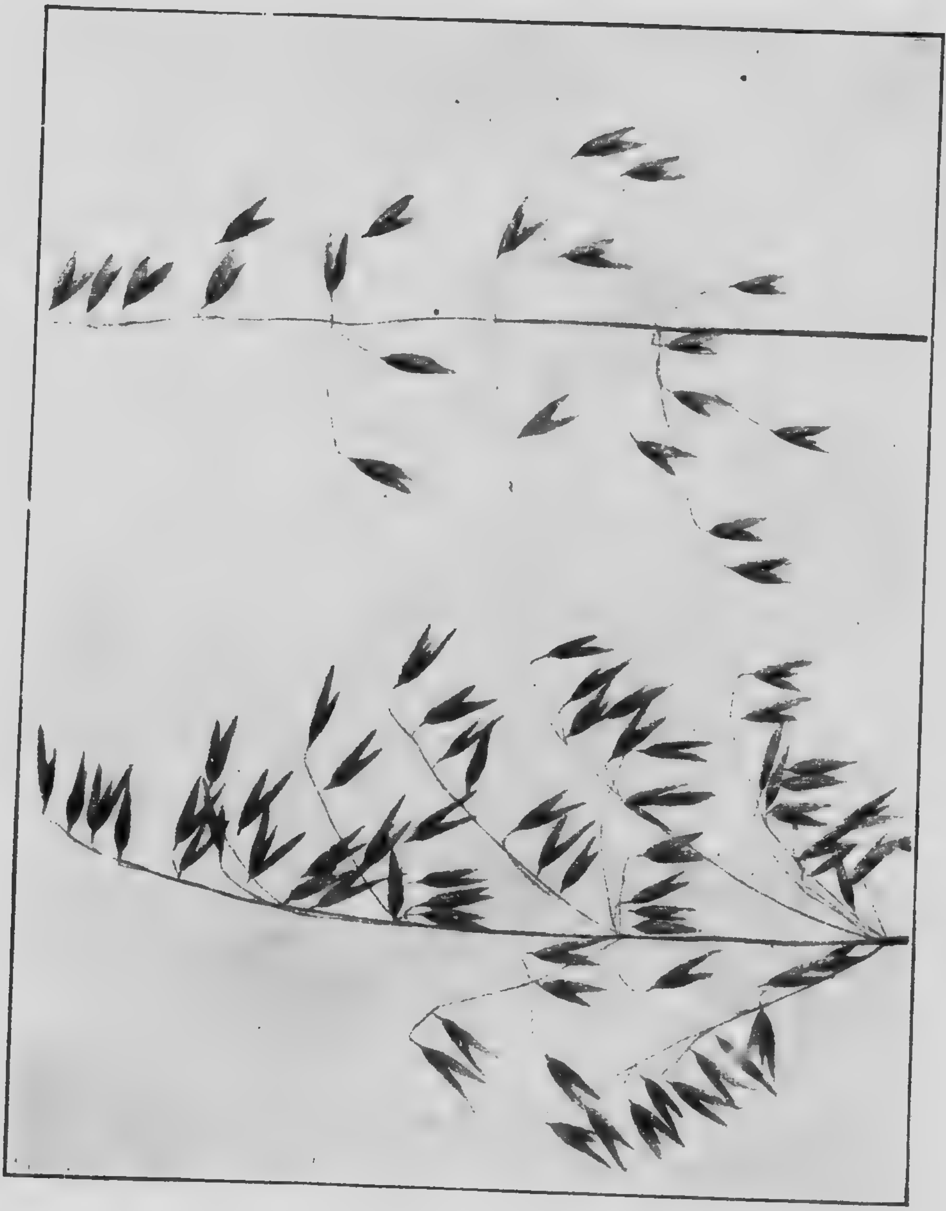
* Bolin resigned his position at Svalöf in 1900, when Tedin took over the barley work in addition to that which he already had with peas and vetches



a b

Fig. X. Type of

Photo by Courtesy S. S. Ass'n.

Photo by Courtesy S. S. Ass'n.

Fig. V.—Types of Panicles in Oats,—a, stiff upright; b, drooping.

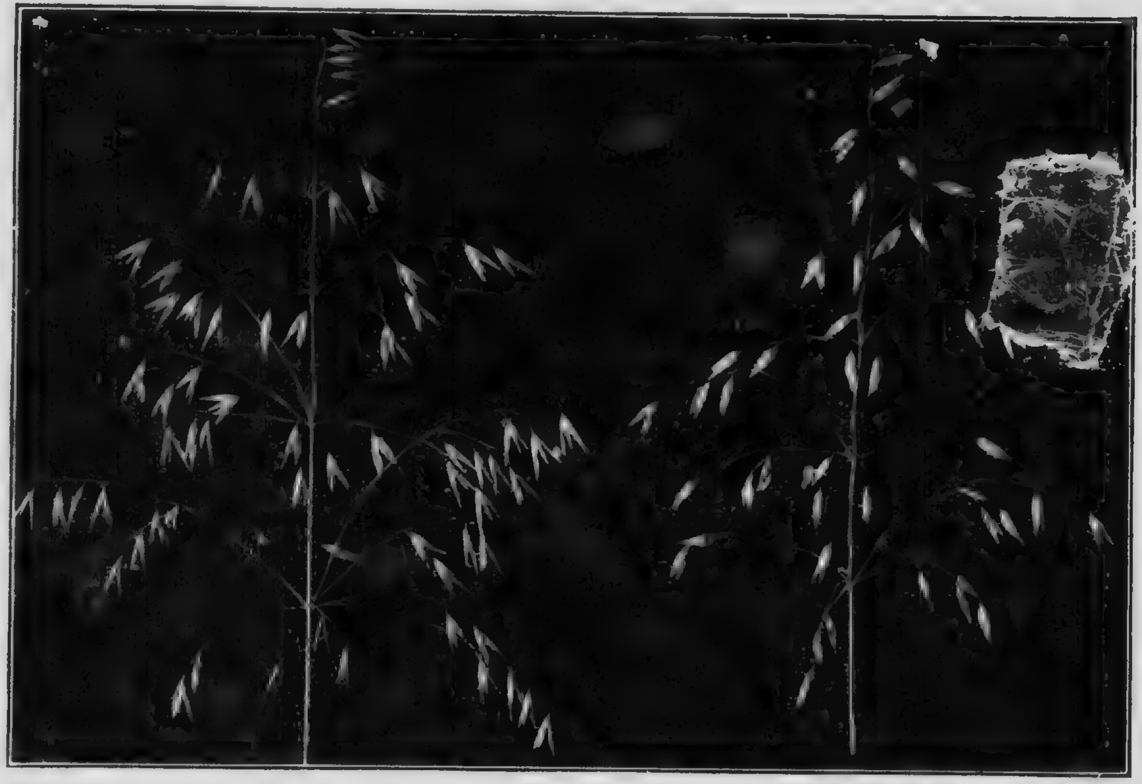


Photo by Courtesy S. S. Ass'n.

Fig. VI.—Types of Panicles in Oats. c, broad, widely spreading; d, narrow ovoid with irregularly bowed main branches.

as a distinct species (*Avena orientalis* Schreb.), forms a fifth. In comparing these types with the industrial values of the sorts it seemed to be shown that the group in which the panicle assumed a more rigid upright position was as a rule the most productive. Such a conclusion, however, has had to be modified since investigation of the tables of yields of the different sorts over many years shows that among the stiff panicled sorts are to be found many which are among the lowest average yielders of all those tested. As instances, may be mentioned the sorts having the stock-book numbers 0310, 0326, 0404 and 0452. There cannot therefore be accepted as an infallible guide, any definite type of panicle.

Relation between compactness of head and strength of straw.

In wheat and oats the character of the head was believed to be associated with strength of straw, investigations seeming to show that a dense, compact head and a stiff, strong straw go together. Here again numerous exceptions have caused this idea to be modified.

Relation between number of kernels in the spikelet, and yield and quality.

Highly interesting investigations into the relationship between the number of kernels in the spikelets of oats and wheat and the yield and quality of the crop were made by Nilsson during the years when these crops were under his direct charge. The number of kernels in a single spikelet of oats is usually from one to two, although three is not uncommon. In wheat as many as six may be found, although from three to four is generally the case. For purposes of investigation Nilsson defined three classes of spikelets: three-kernelled (S_3), two-kernelled (S_2) and one-kernelled (S_1). These are illustrated below.

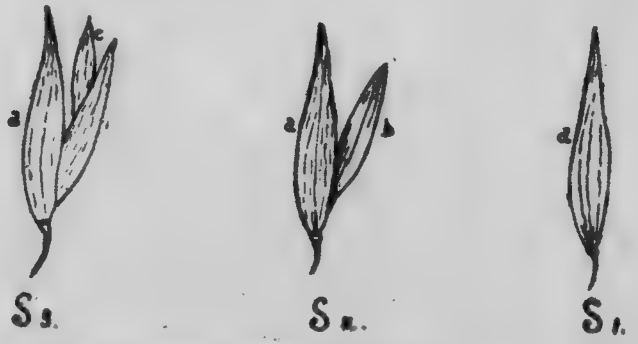


FIG. VII.—Different Classes of Spikelets. (Author del.)

It would seem natural to conclude that in spikelets such as S_1 which contain but one kernel (a) that this would be larger than kernel (a) in S_3 which contains three kernels. The following, however, was found to be the rule:—

1. "That the development and weight of each kernel stand in a striking and significant relation with the number of kernels in the spikelet; but

2. "That with a *rising* number of kernels there is associated a considerable *increase in weight per kernel* instead of the opposite which one would expect.

"Kernel (a) is never so small and miserable as when it is alone as in S_1, and never so heavy and well developed as when it is accompanied by two other kernels as in S_3" (27, p. 18; 28, p. 183).

This striking fact is clearly demonstrated in the following table which gives the weight of each kernel in the three-kernelled spikelets, in two-kernelled spikelets and in one-kernelled spikelets found on the one plant in each case:

Types investigated.	Average weight per kernel in milligrams						Per cent of each class of spikelet in plants studied.			
	In three-kernelled spikelet (S_3)			In two-kernelled spikelet (S_2)		In one-kernelled spikelet (S_1)				
	a	b	c	a	b	a	S_3	S_2	S_1	Total.
Plants from Probstier type	54	38	14·80	44	28·25	33·50	14	82	4	100
Plants from Ligowo	60	42·8	16·75	52·63	32·70	31·00	13	83	4	100
Plants from side-oat types	50	34	10	38·13	20·23	27·93	11	74	15	100
Plants from new types of stiff-panicled black oats	50·66	30·16	9·33	40·41	22·68	27·08	9	82	9	100

As [illegible]ult of his investigations Nilsson concluded that "oat sorts having [illegible]est number of kernels per spikelet are decidedly the most valuable [illegible] 19 and 27). The same conclusion was arrived at in wheat, thus: "Even in wheat the highest possible number of kernels per spikelet is an especially desirable character, as it carries with it an improved crop not only in respect of quantity but still more in quality" (28, p. 205). In arriving at these conclusions Nilsson made certain reservations, thus: "It now remains for a series of years' testing in larger practice finally to confirm or disprove my here expressed opinion" (28, p. 210). Fifteen years have passed since the above statement was made and it is now only necessary to compare the best sorts of to-day with the number of kernels per spikelet by which they are characterized in order to determine the correctness of these early opinions. Thus the two best oat sorts at Svalöf at present, viz.:—*Victory* and *Gold Rain*, are classified as two-kernelled sorts. On the other hand certain other high yielders, such as *Danish Nasgaard* are, with relative regularity, three-kernelled. Conversely it has been found that certain relatively low yielders, such as *Hvitling* and *0313* are also three-kernelled sorts, while others again, such as *White Probstier* are classified as two-kernelled. There seems therefore to be no definite relationship between the yield of a given strain and the number of kernels per spikelet by which it is characterized.

As regards quality (absolute weight of kernels and percentage hull) the two-kernelled sort *Gold Rain* stands in the foremost rank, being especially noted for its high weight and low per cent hull. The number of kernels per spikelet by which sorts are characterized cannot therefore be regarded as an indication even of quality.

The present attitude of Nilsson-Ehle and Tedin toward this question is that a large number of kernels to a spikelet is indicative of higher yield only in the case of fluctuating individuals within one and the same pure line, but is of no special significance when it concerns the variety as a whole. This may at first seem contradictory but one must keep in mind that yield is the product of many different factors, so that it is quite possible for a sort having many kernels to a spikelet to still give a relatively low yield. Interesting investigations in Germany by Böhmer (4, p. 50) and in Norway by Christie (10, p. 39) seem to confirm these conclusions. Christie worked with ten pure lines of Norwegian grey oat, fourteen of Norwegian white oat and eighteen of Probstier oats during 1909 and 1910. His studies show that the greater the number of kernels in the spikelet the greater is the weight of kernels per plant in the case of different plants *within the same pure line,* but in the case of different pure lines this relationship is not shown. "In comparing pure lines from the same old variety of oats I do not find," he says, "any reason to attribute any special value to three-kernelled spikelets. The absolute weight of kernels per plant gives much more certain information regarding the productivity of the stock and is, moreover, essentially quicker and easier to determine."

While the value of different strains cannot be judged by the number of kernels which are borne by each spikelet, yet a distinction can often be made on this basis between *different lots of the same strain grown under different conditions.*

Environment plays an important part in determining the number of kernels borne in the spikelet. Under certain conditions a sort which is normally three-kernelled will develop only two-kernels in a large percentage of the spikelets. Conversely a sort which is ordinarily classified as two-kernelled may sometimes produce a large percentage of three-kernelled spikelets.

Relationship between date of maturity and yield.

It has long been held by many that early maturity and high yield are antagonistic or, in other words, that high yield and late maturity are correlated. This idea has had to be modified considerably within recent years owing to the appearance of a number of high yielding yet early maturing sorts. Thus at Svalöf *Sun wheat, Hannchen barley* and *Gold Rain oats,* all high yielding sorts, are nevertheless relatively early maturers.

Origin of Primus Barley.

As an example of the course of procedure followed when attempting to isolate distinct botanical forms as mother plants on the basis of correlations, there is cited in one of the station journals (34, p. 51) the isolation of a form of brewing barley which afterwards received the name *Primus.* The account of the origin of this sort, as given in this article, is substantially as follows:—

Efforts to obtain a stiff strawed sort from the high quality but weak strawed Chevalier having failed, attention was turned, about 1893, to a stiff-strawed but poor quality "Imperial" barley with the hope that this perchance, might include forms having the short-haired rachilla of the Chevalier kernel (which was supposed to be correlated with high brewing quality) and at the same time possessing the strength of straw of the Imperial. Thousands of plants were examined and out of these a few dozen were discovered which showed the desired character. These were planted out in separate cultures and their progeny studied with the result that eight years later (1901) the progeny of one of the best of these came on the market under the name *Svalöfs' Primus*, (0706).

The above account has been cited by DeVries (79) "as an illustration of the high significance of these correlations," a citation which has been widely quoted in America. An examination of the origin of the mother sort from which *Primus* was taken, however, seems to throw an entirely different light on the situation and to nullify the arguments presented as to the value of correlations, at least in so far as this particular case is concerned. Thus the so-called "Imperial" barley referred to as the mother variety of *Primus* was imported from Germany for testing at Svalöf under the name *Diamond*. This was originated by Bestehorn of Germany and listed in the German seed catalogues as a crossing product of certain parentage. The opinion that this sort was actually of hybrid origin was expressed by Bolin (5, p. 61) in 1893 and later (7, p. 10) was more fully discussed by the same author in one of the leading periodicals of Sweden, substantially as follows:—

"Among the various barley sorts imported from Germany for testing at Svalöf was one known as the *Diamond* barley. This was said to be a crossing made by Bestehorn, a German breeder, between a Nutans form (probably Chevalier) and *Imperial* which belongs to the Erectum type. The hybrid *Diamond* was found to be mixed (unfixed) the majority of the plants resembling *Chevalier*. Among the whole population were found a few plants, the kernels of which showed a union of the short woolly-haired rachilla of the *Chevalier* with the peculiar character of the base of the kernel of *Imperial* and thus were regarded as the result of a true crossing between the two. The plant from which *Primus* originated was one of these"

If this sort is actually a crossing product, as Bolin insists, it affords an excellent example of the value of hybridization as an aid to the breeder. At the same time the circumstances which surrounds its origin, together with the fact that sorts which have the supposedly undesirable character of kernel have proven quite as satisfactory for brewing as have those which were regarded as especially suitable for this purpose, deal a severe blow to those who have sought to show the importance of correlations in forming direct judgments as to practical values.

Speaking of these correlations in barley Tedin says: "I do not believe in the existence of correlations between different simple characters by which a certain character is said to indicate the nature of another, but regard such as being simple manifestations of the *same* unit-character" (73, p. 8–9).

The inability to judge practical qualities from other characters in accordance with the idea of correlations is also pointed out by Johannsen (16), **Kølpin Ravn** (58) and other workers of recent years.

In Denmark important investigations into the question of correlations have been prosecuted for many years. A few examples will here be cited. As is well known by all breeders, different pure-lines or strains have their

Weight per 1000 kernels vrs. yield.

own characteristic weight of seed. That no relationship exists between weight per 1000 kernels and yield is clearly shown by Vestergaard of Abed Experimental Station, Denmark, in the following table (80, p. 51):

Sorts arranged according to yield.	Weight per 1,000 kernels. (Grams.)
Squarehead Autumn wheat	45
Golden Drops " "	47
Kolbe " "	45
Urtoba " "	54
Kent " "	50
Gl. Danish " "	43
Prentice, Two-rowed barley	47
Chevalier " "	46–47
Native " "	47
Goldthorpe " "	52
Crossing " "	53
Imperial " "	54 (?)
No. 45 Oats	36·3
" 39 "	34·2
Danish "	35·0
White Banner "	32·2
Beseler "	35·0
Ligowo "	36·5

Twelve oat sorts grown at Svalöf are arranged below according to yield. Opposite each sort is given its corresponding standing as regards weight of kernels:

According to yield.	According to weight of kernel.
No. 1	No. 10
2	7
3	9
4	5
5	4
6	6
7	11
8	2
9	3
10	1
11	12
12	8

From the above tables it will be seen that some of the most valuable strains possess only medium sized kernels. This fact at once exposes the danger, when dealing with an ordinary variety which may consist of large, medium and small kernelled strains, of over-sorting or grading, that is retaining for seeding purposes only the very largest kernels. In such cases a *uniform sample of plump, medium sized kernels* should be sought for. The use of pure strains of course obviates this difficulty entirely and herein lies one of the many advantages of such strains.

Size of head vrs. yield.

In selecting heads of grain by mass-selection from mixed races with a view to increasing the yield the natural tendency is to select the largest. This is shown to be an unsafe practice. As is size of kernel so is size of head a sort-character. Certain pure lines of outstanding value have been found to possess a relatively small head while many inferior strains are characterized by strikingly large ones. In other words there seems to be no definite relationship between size of head and yield. A few examples will suffice to show this: In barley, Princess and Chevalier though high yielders, have relatively small heads while Imperial and many other inferior sorts have heads of large dimensions. In wheat, *English Stand Up* and *Tystofte Small* which are among the most productive sorts, are noted for the relative smallness of the head. The continued selection of extra large heads from a composite race which happens to contain both large and small headed strains can therefore easily prove an injury rather than a benefit. An excellent illustration is afforded by Vestergaard, in his investigations with the common Prentice barley (l.c. p. 106). Out of this variety there was isolated, among others, a certain group representing 4—6% of the whole and which was characterized by long coarse straw and large heads. A comparison between pure lines from this group and from the mother variety is given below as follows:

Dangers associated with mass-selection.

	Yield of grain per Td. Ld. (about 1 acre) kilograms.	Length of straw in c.m.	Length of head in m.m.	Weight of 100 heads in grams.	Per cent of shoots bearing heads.
24 Pure lines from the common Prentice type...........	4350	89·5	77·8	68·4	74·6
8 Pure lines out of the long strawed large headed group..................	4076	93·3	84·0	80·9	67·0

A mass selection of heads from the long strawed, long headed group would obviously lead to decreased yield in this case.

Stooling in grain vrs. yield and quality.

The question of stooling or the developing of 'side shoots' in cereal grains and its relationship to yield and quality has also been investigated. As most growers know the power to 'stool' varies more or less with different sorts. Under certain circumstances this characteristic may be of considerable practical value. Thus where the stand is thin as a result either of thin seeding, the attacks of disease or insects or of some other agency, the powe to stool and thus in a measure at least to compensate the loss, is obviously a characteristic of importance. Sorts which normally develop several straw from the one seed have long been regarded by many as superior to those in which the stolons are more sparse.

Prof. E. Schribaux of Paris, and certain other workers, however, have expressed opposite views. Schribaux (60) claimed that the so-called 'main' stem reaches the best development and produces the most grain and the best quality, thereby being of greater value than those which develop later. Later, investigations of Rimpau (61) and Lippoldes (21) indicate the weak points in Schribaux' work and the incorrectness of his conclusions.

When the work at Svalöf was begun it was insisted that no plant of more than three stems should be selected and that these be as evenly developed as possible. This rule led to no results of special significance and so was finally abandoned. With the introduction of the pedigree system a large number of pure lines came to be studied thereby providing excellent opportunity for further elucidation of this question. As time passed Tedin observed in barleys that certain sorts which one year were recorded as "heavy stoolers" were other years designated as "light stoolers" and vice versa. This and other perplexing irregularities induced him to submit the whole question to a thorough investigation which covered the years 1903, 1904, 1905 and 1907 (74 p. 292). The conclusions drawn from these investigations are that while a given sort may possess its own stooling propensity yet this, especially in the case of barley, plays so small a part in comparison with the effects of life-conditions as to be almost unworthy of mention. On the other hand more marked differences are shown to exist between sorts in respect of their *manner* of stooling. In some sorts for example the side shoots develop very unevenly while in others the development is uniform, thus allowing even maturity and conducing in a large degree to good quality. Such a sort is obviously to be preferred.

In 1903 careful observations were made by Nilsson-Ehle respecting the stooling properties of different oat sorts. A few examples taken from the records are given as follows:—

Sort	Number of stems per plant.	Relative yields.
Probstier Group:—		
Gold Rain	2·07	High yielder.
Victory	2·72	" "
Hvitling	2·3	Lower yielder.
White Probstier	2·13	" "
No. 0127	2·42	" "
Lines out of Black Tartarian:—		
No. 0201	2·	Relatively low yielders and light stoolers.
No. 0202	1·78	
No. 0204	1·93	
No. 0229	1·75	
From natural crossing between Black Tartarian and Probstier.—		
No. 0495	2·41	
No. 0496	2·08	
No. 0497	1·96	
No. 0499	2·91	Best yielder and heaviest stooler of this group at the Ultuna Station.
Lines out of Black Swedish oat:—		
Fyris	2·86	Best yielder in this group.
No. 01026	3·07	
No. ——	4·00	
No. 01062	2·61	
No. ——	3·37	
No. 0275 (Nigger)	3·83	Heavy stooler and poor yielder.
No. 0202 (Black Tart.)	1·78	Very light stooler and poor yielder.

The above data clearly indicate that while rather marked differences can often be detected in oats in respect of their tendency to stool, yet it is quite unsafe to accept 'stooling propensity' as a basis of sort valuation.

In 1904 Vestergaard (80 p. 107) studied 67 different strains of barley representing in all about 20,000 plants, each of which was grown on from two to three different plots. This material was divided into four different classes according to yield and the following data obtained:—

Class	Number of strains	Comparative yield	Number of head-bearing straws per plant	Per cent head-bearing straws per plant	Length of straw (c. m.)	Grain. Per cent of total crop	Numbe of head bearing straws per 16 sq. ft
1	17	100	2·13	74·6	92·9	48·7	1038
2	17	96	2·07	74·1	93·3	47·9	981
3	17	95	1·97	72·2	93·9	47·7	952
4	16	87	1·96	69·0	95·8	46·7	929
	67						

From the above table it will be seen that contrary to the theory o Schribaux, the most productive strains have in this case at least the greates number of head-bearing straws per plant, and a considerably smalle number of sterile or non head-bearing shoots. The best strains have als shorter and finer stems and produce a higher proportion of grain to straw. They are thus less striking than those which proved actually less productive. Further evidence is thus provided regarding the uncertain relationship existing between morphological characters and the real worth of a given sort. *Of greater importance is thickness of stand, even development of stolons and heads or panicles and the general appearance of the crop as regards vigor and freedom from disease.*

The system of exclusive Form Separation abandoned

The above investigations seem to indicate clearly that the practical value of a sort cannot be judged indirectly by means of botanical marks or morphological characters with any degree of certainty or reliability. Neithe can so-called "ideal" plants be located with assurance in a mixed population on this basis. To quote Nilsson-Ehle (45, p. 311), "the great difficulty in breeding is to decide whether or not a form constitutes an *advance*. That this can be decided only in a purely empirical way, through long continued practical experiments is essentially what makes breeding work so long."

These conclusions served to introduce a second method of applying the pedigree system at Svalöf. Thus *instead of basing the isolation of superior individuals purely upon botanical or morphological characters as was formerly the case, the principle has become to select a large number of individuals without special regard to such characters.* The valuation of these individuals in so far as yield is concerned, rests upon yielding tests conducted with the greatest possible care over a series of years.

In order that this direct judgment might be more effective and more quickly accomplished local sort trials and special forms of comparative tests have been introduced. This change in method has naturally rendered breeding work much more difficult and exacting, especially where yield is the chief consideration. The alacrity and assurance with which an individual or sort was formerly rejected when failing to measure up to certain *ideals* in regard to visible characters, is no longer regarded justifiable, but instead extreme caution is observed lest unsuspected values be overlooked or lightly cast aside.

IV. THE COMPOSITION OF A RACE OF CEREALS AND ITS VARIABILITY

Biotypes and Elementary species.

From the evidence adduced thus far it seems clear that at least some of our common cultivated varieties contain a larger or smaller number of distinct hereditary types which, on being propagated separately, breed true. Johannsen, as already indicated, has given to these entities the name *Biotypes*, the progeny of which he calls a "pure line." Such bio-types, together with other intra-specific forms, are commonly spoken of by DeVries, as "elementary species." In self-fertilizing plants such as wheat, oats and barley, pure lines may correctly be called *strains*, although this term is not always restricted to absolutely pure sorts. In this paper *strain* will be used to indicate pure lines only.

The presence of different types within a variety was formerly regarded as a manifestation of some inherent (hereditary) variation, a phenomenon which was believed to be continuous. Experience in the separate culture of these types, however, has shown them to be constant and distinct entities representing probably the smallest systematic division into which plant life can be divided.

Multiformity of Probstier oats.

One of the most composite varieties of agricultural plants investi[illegible] thus far at Svalöf is the variety of white oats commonly grown in the Ba[illegible] region and known under different names of which *Probstier* is the most common.

In commenting upon the mixed character of this variety, Nilsson-Ehle (42, p. 125) says: "The multiplicity of forms found within this old unselected race is so great that it is difficult to obtain two individuals which will give identical progeny." The respective progeny of these forms were distinguished by differences in degree of *awn-development hairiness of callus, size, form and color of kernels, average height of straw, width of leaf*, etc.

Inability to distinguish all biotypes on the basis of outward appearance.

The fact that two apparently identical plants in an old race may, when cultivated separately, prove to be quite distinct bio-types each producing its own peculiar progeny, served to show the need of submitting old varieties to an actual biological analysis. This analysis it was seen, could not be restricted to forms which simply appeared different, but must rather embrace a large number of individuals without special regard as to whether these differed in outward appearance or not.

This is the principle which has been followed by the above author in connection with the extensive analysis to which he has subjected the old Probstier variety during the past ten years. The results of one of these lines of studies may here be given: In 1906 there were sown out 72 small plots, each with seed from a single plant taken at random from a variety belonging to the Probstier group. The following table gives t analysis of each of these plots (42, p. 118):—

No. of plot	Color of kernel	Frequency of awns. %	Character of awns.	Hairiness of callus.	Average length of kernels (m.m.)	Average width of kernels (m.m.)	Weight per 100 primary kernels (Grams.)	Notes on other characters
1	white	0	..	1	16·0	2·99	4·08	
2	“	2	..	1	17·1	2·97	4·09	Weak strawed
3	“	4	1	0	15·3	3·18	4·01	
4	“	5	1–2	0	15·5	3·08	3·98	
5	“	7	1	1	16·7	3·12	4·30	Spikelets often 3-kernelled; plants broad leaved.
6	“	7	1	2	16·2	3·01	3·91	
7	“	11	1	1	15·2	3·10	3·96	Stiff strawed.
8	“	11	1	2	16·9	2·99	3·86	Spikelet often 3-kernelled.
9	“	11	1	1	15·0	3·03	3·81	
10	“	12	1	2	15·4	2·89	3·60	Spikelet often 1-kernelled; plants short strawed.
11	“	12	1	2	16·1	3·10	4·14	Tall.
12	“	17	1	0	17·0	3·14	4·46	
13	“	17	1	0	15·9	3·10	4·09	
14	“	19	3	0	16·8	3·08	4·21	
15	“	22	1	0	16·4	2·89	3·81	Tall.
16	“	22	4	0	15·3	3·08	4·10	Early shooting of panicle.
17	“	25	1	2	16·2	2·83	3·57	
18	“	25	1	1	15·5	2·91	3·71	
19	“	25	2	2	16·2	2·89	3·87	Tall.
20	“	26	2	0	15·2	3·22	4·08	Short.
21	“	26	1	1	16·2	3·10	4·20	
22	“	28	2	0	16·9	3·12	4·32	
23	“	34	1	2	16·6	2·91	3·76	
24	“	41	2	1	16·9	3·16	4·40	Spikelets often 3-kernelled; panicle one-sided.
25	“	42	1–2	0	16·9	2·95	4·00	Spikelets often 3-kernelled.
26	“	43	1	2	16·8	2·93	3·94	
27	“	45	2	0	16·5	2·89	3·85	
28	“	47	3	2	16·9	3·06	4·07	
29	“	48	3	1	16·1	3·08	3·98	Late shooting of panicle.
30	“	48	2	0	17·0	2·97	4·22	Weak strawed.
31	“	50	2	1	16·4	3·03	3·87	
32	“	50	2	2	16·3	2·97	3·89	Early shooting of panicle
33	“	50	3	0	17·8	2·95	4·09	Spikelet often 3-kernelled.
34	“	54	3	2	16·4	2·97	4·17	
35	“	60	1	0	17·0	2·93	3·92	
36	“	62	2	0	16·6	2·99	4·08	

No. of plot	Color of kernel	Frequency of awns. %	Character of awns.	Hairiness of callus.	Average width of kernels (m.m.)	Average length of kernels (m.m.)	Weight per 100 primary kernels (Grams.)	Notes on other characters
37	white	63	1	0	16·4	3·01	4·23	Short, stiff strawed.
38	"	64	4	2	14·9	3·26	4·47	
39	"	69	2	2	14·9	2·97	3·82	Tall, broad leaved.
40	"	69	4	2	15·1	3·03	3·84	Tall.
41	"	70	5	0	17·1	2·85	3·93	
42	"	71	2	1	16·1	2·93	3·69	Short, late shooting of panicle
43	"	71	3	2	17·6	2·89	3·85	Spikelet often 3-kernelled, tall, panicle almost plume-like.
44	"	74	3	0	15·4	2·97	4·09	
45	"	77	2	2	17·4	2·97	4·04	Spikelet often 3-kernelled.
46	"	79	2–3	0	17·0	3·08	4·19	Tall.
47	"	79	2–3	2	17·1	3·03	4·17	Weak-strawed, late shooting of panicle.
48	"	80	2	2	16·5	2·93	3·90	
49	"	84	3	1	16·1	3·14	4·34	
50	"	85	2	2	17·4	3·06	4·09	Spikelets often 3-kernelled; plants short strawed.
51	"	85	2–3	2	16·9	3·03	4·01	
52	"	85	2	0	15·6	2·99	4·02	
53	"	87	2	2	16·4	2·91	3·78	
54		89	2	2	15·8	2·99	3·89	Late shooting of panicle.
55	"	89	5	0	18·6	2·97	4·19	Spikelets often 3-kernelled.
56	"	91	4	2	18·2	3·01	4·50	Spikelets often 3-kernelled.
57	"	95	4	0	16·4	2·99	4·28	
58	"	98	2	1	17·9	3·14	4·55	Spikelets often 3-kernelled.
59	yellow	0		2	17·0	2·89	3·70	
60	"	1	1	1	16·7	3·12	4·20	
61	"	1	1	2	16·9	2·89	3·88	Tall.
62	"	2	..	0	15·5	2·99	3·64	Short.
63	"	4	1–2	1	16·5	2·81	3·62	
64	"	5	2	1	16·8	2·81	3·49	Spikelets often 3-kernelled.
65	"	5	1	0	15·7	2·99	3·86	Tall.
66	"	15	1	0	16·4	2·93	3·79	
67	"	17	2	2	16·5	2·85	3·67	
68	"	17	1	1	16·6	2·87	3·61	
69	"	23	4	2	16·7	3·12	4·18	
70	"	23	2	2	17·3	2·95	3·90	Spikelets often 3-kernelled.
71	"	24	2	0	16·8	3·06	4·30	Weak-strawed.
72	"	27	1–2	1	16·3	2·91	3·89	Short.

It is worthy of notice here that the various characters by which the 72 strains considered in the above table are distinguished, group themselves around an average or "*mean*" according to the law of Quetelet, that is, the greatest number are found to possess the average condition of a given character. This may be illustrated by taking the average length and weight respectively, of the primary kernels of each strain thus:

Number of strains having length of kernel indicated in opposite column.	Average length of kernel of each strain in millimetres.
2	14 to 15
16	15 to 16
38	16 to 17
14	17 to 18
2	18 to 19
72 strains	

Number of strains having weight per 100 kernels indicated in opposite column.	Average weight of 100 kernels in each strain. (Grams.)
2	3·4 to 3·6
11	3·6 to 3·8
23	3·8 to 4·0
21	4·0 to 4·2
10	4·2 to 4·4
5	4·4 to 4·6
72 strains	

The situation indicated in the preceding tables may be expressed in still another manner. Let us consider the second table in which the weight is given. It was found in this case that the weights of 100 kernels from the different strains fell into classes as follows:

Weight in Grams . .	3·4 to 3·6	3·6 to 3·8	3·8 to 4	4· to 4·2	4·2 to 4·4	4·4 to 4·6
Frequency .	2	11	23	21	10	5

The classified data may be arranged graphically, in the following manner, to show what the Biometricians call "the frequency curve of variation in the weight of kernels":—

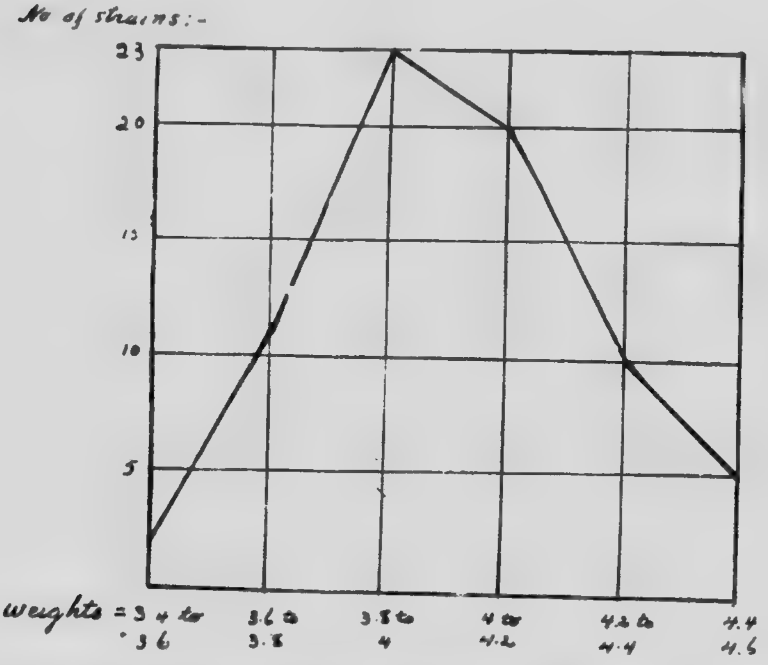


FIG. VIII.—Frequency curve of variation in weight of kernels from different pure cultures (Author del.)

The different types in the large table shown above are arranged according to the per cent of plants in each which developed awns. This, it will be noticed, varied from 0 to 98% in the white kernelled sort and from 0 to 27% in the yellow. The character of the awns (finer or rougher) is measured by the eye, (1) indicating a fine, weakly developed awn and (5) an awn which is strong and twisted.

The hairiness of the callus is also measured by the eye, (0) indicating absence of hair, (1) slightly hairy and (2) heavily haired.

The above analysis shows that scarcely any of the 72 plots produced identical progeny but rather are they regarded as distinct hereditary types which in respect to certain characters present a whole line of hereditary gradations from one extreme to another.

Independent nature of different characters.

A point of prime importance revealed by these investigations is the *independent nature of different characters.* Thus the development of awns is quite independent of the development of hair on the callus; the length of the kernel is in no way governed by its breadth: low growing forms as well as high may have broad leaves or narrow leaves or they may have a stiff-branched panicle or a panicle which is more lax and drooping etc. Each biotype in fact represents *a definite combination of characters.* Those familiar with the law of Mendel may find in this fact, further support for the conception that these forms have arisen through natural crossing.

Interesting observations regarding the variability and multiformity of distinct hereditary types found within this same variety of oats (Probstier) as well as in Squarehead wheat and Two-rowed barley have been recorded by Vestergaard of Denmark (80 p. 77–119). In Squarehead Wheat he distinguishes ten distinct biotypes on the basis of *form of head.* Although this variety is normally smooth chaffed he has found forms with velvet chaff which he believes to have originated from the genuine squarehead type. Bearded heads have also been found although Squarehead is a bald wheat. Certain cultures were further found to represent distinct biotypes on account of differences in size, form or color of leaves, although no marked differences in the head could be noted. Many cultures were readily distinguished on the basis of form, size and color of kernel and the degree of susceptibility to disease by which each was characterized.

In Denmark the most commonly cultivated two-rowed barleys are the so-called *Danish Native barley, Chevalier barley* and *Prentice barley.* Of the latter Vestergaard has cultivated about 400 separate cultures, a number of which have shown themselves to be distinct biotypes, although as a whole this variety has proven much less composite in character than has the common Danish barley. Reference has already been made in another connection (See p. 39) to the groups of distinct forms which have been taken out of this variety and specially investigated.

Numerous Combinations possible by crossing.

Natural crossing in cereal grains.

In view of the independent nature of the different characters which go to make up the individual it is possible for these to group themselves into almost every conceivable combination by cross-fertilization, artificial or natural. That such grouping actually takes place seems to have been shown conclusively by the enormous amount of work in artificial hybridization which has been prosecuted with all kinds of Agricultural plants during the past ten years. It seems natural to suppose therefore that at least the great majority of the different strains or biotypes found within the old Probstier and other races and which represent different combinations have arisen by natural crossing. That natural crossing between sorts, even in such self-fertilizing genera as those to which wheat, oats and barley belong may occasionally take place has been clearly pointed out by such recognized authorities as Rimpau (60), Kornicke (20), Kiessling (19 p. 73), Nilsson-Ehle (49 p. 15) and Tedin (71 p. 119).

The multitude of distinct hereditary combinations which may arise through a relatively small number of independent differentiating units was pointed out by Mendel who showed that only 10 such units are necessary to make possible as many as 1,024 different constant (homozygous) combinations. Since it is easily within the range of two hereditary types to differ in as many as 10 different characters it is only necessary that these become crossed in order to produce a multiformity of combinations corresponding exactly with that which is represented in an old mixed variety.

The progeny of a crossing are of course hybrids and according to the law of Mendel, a certain proportion of these become practically constant in succeeding generations. Others segregate or divide producing constant (homozygous) and inconstant (heterozygous) combinations. The latter continue to segregate until so reduced in proportion to the constant forms as to finally become practically lost sight of in the case of normal self-fertilizers. Thus in the end are to be found a whole host of constant combinations each of which, further crossing excluded, breeds true in succeeding generations.

The constancy of pure lines in self fertilizing species of plants seems to displace at one stroke practically all previous conceptions regarding the question of variation. We must abandon the idea that all life is in a constant state of unrest, always varying this way or that. "Had this analytical principle" says Johannsen, "been used in the times of Darwin or had it even been appreciated by the Biometrician school certainly the real bearing of selection might long since have been rightly understood" (18 p. 143).

Individual and partial modifications within pure lines.

By reason of the variability of soil, moisture, light and other external factors there are always to be found a larger or smaller number of individuals *within* a pure line which deviate from the common type. There are also to be found variations between certain *parts* of individuals. The first form of variation can best be designated as *individual variation* (modification), and the latter as *partial modification.* Neither, however, is regarded as hereditary. These modifications may be sufficient to cause certain individuals, within a given strain to "transgress" or "over-lap" those in another. Thus a plant belonging to a certain strain may become so altered by external conditions as to become apparently identical with that belonging to another. An excellent example is afforded in connection with the various strains taken out of the Probstier oats. The length of each individual in six of these strains is indicated in the following diagram (42, p. 128);—

Length of straw in centimetres.		95	100	105	110	115	120	125	130	135	140	145	150	155
Six strains from Probstier Oats.	*a*	1	3	5	8	7	5	1	..	..	..	..	..	..
	b	..	1	1	9	12	17	7	2	1	..	..	..	..
	c	1	1	1	3	4	8	13	8	2	2	..	..	..
	d	..	..	..	1	3	8	13	15	7	2	..	..	..
	e		..	..	..	..	2	2	6	7	13	18	5	..
	f	..	..	..	..	..	..	..	1	..	6	9	19	8
		2	5	7	21	26	40	36	32	17	23	27	24	8

A study of the above diagram clearly indicates that a direct botanical examination of a common population can give scarcely more than an indication of its constitutents. Only by the separate culture of a sufficient number of individuals and by a determination of the average condition of each character in the progeny can an effective analysis be made. It is this *average condition* which distinguishes one strain from all others. This fact constitutes a second great reason why the isolation of superior mother plants as starting points for new races cannot depend exclusively upon appare morphological differences.

Influence of mass-selection.

In commenting upon the influence of mass-selection, in a case such this, Nilsson-Ehle (42 p. 128) says: "Were a mass-selection of plants ov 125 c.m. in height to be made from this old mixed sort, plants from typ which normally produce a short straw would be taken as would also those fro types which normally produce a taller growth. The latter would naturall preponderate whereby a certain advance in the desired direction would likel be made." It is quite possible, however, that an advance in one directio may be made at the expense of some more valuable quality, hence th danger which is associated with this form of selection.

The Origin of Aberrant Forms as Quantitative Hereditary Variations.

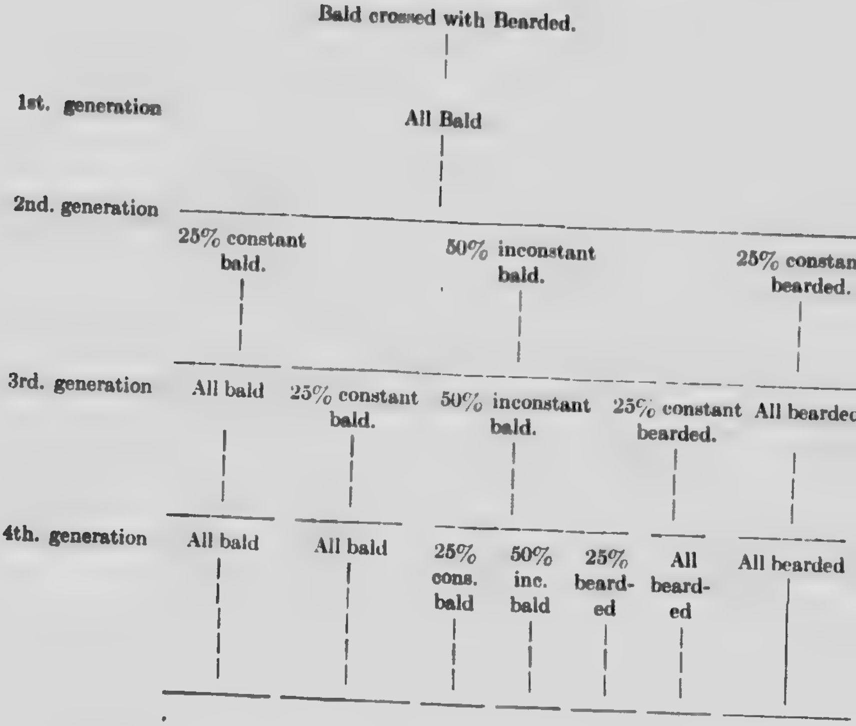
Apart from the mass of apparently related individuals which go to make up the greater part of a plant population, there may occasionally arise *strange forms* which at first sight do not seem traceable to any definite parentage. There may arise bearded heads of wheat in a bald sort, brown-chaffed individuals in a white-chaffed sort, white-kernelled forms in a red-kernelled sort, etc. In oats, white and grey kernelled individuals have been found in black-grained sorts and vice versa, while side oat types have been found in sorts characterized by spreading panicles. Formerly these aberrant forms were commonly regarded as Atavists or Reversions, being looked upon as the sudden reappearance of certain ancestral characters. More recently they have received the name Mutation. Experience at Svalöf and elsewhere has shown that the majority of these so-called novelties which thus suddenly appear in cultivated crops may be produced artificially by cross-hybridization and may therefore be regarded in most cases, simply as new combinations of already existing units. Apart from the great scientific interest which surrounds the appearance of these aberrant individuals there is an interest for the practical breeder which cannot be denied. If these forms represent *mutations* by which apparently new characters are suddenly acquired, it would clearly be the breeder's main duty to watch carefully for their appearance in his fields with a view to isolating and propagating them and perchance obtaining something better than the old sort. On the other hand, if they represent the results of natural crossings between different sorts, as they are now believed to do, it is of much less importance to spend time in seeking for things which can be produced artificially with much greater assurance of obtaining an advance. Thus where formerly, striking natural crosses found in the experimental plots at Svalöf were eagerly isolated and studied they are now very largely ignored unless the marks by which they are characterized point to a certain parentage of known value. Instead it is preferred to make crossings artificially between known sorts whose values have already been proven.

Mendel's Law of Hybrids.

An explanation of the origin of new combinations is afforded by Mendel's Law of Hybrids. In fact, this law is now the basis of practically all investigation in the realm of hybridism and should be understood by all breeders. Before the law of Mendel became known cross-fertilization was looked upon as *a means of stimulating or creating variation*, making the selection of superior variants possible. The varieties or sorts used for this purpose was not a matter of great concern as almost any two, it was thought, were capable of producing, when crossed, variations which might form the basis of new and better sorts. When Mendel's law became better understood, crossing came to be regarded not as a means of inducing variation, but *as a means of combining already existing units*, allowing certain characters of one parent to be combined with those of another.

One of the requisites for the application of this law is that the two parents possess characters which are opposed to each other. As examples may be cited the simple characters, *Baldness* and *Beardedness* in wheat, *Roundness* and *Wrinkledness* in pease, *Smoothness* and *Hairiness* of wheat chaff, etc. These two opposing characters in each case are termed a "*character pair.*" When one of the characters belonging to a certain pair is "stronger" than the other it is said to be *Dominant*. In this case only this character will appear in the first generation hybrids, the other remaining *recessive* or concealed. In wheats, *Baldness* is dominant over *Beardedness*. The first generation from a crossing between a Bald and a Bearded sort will therefore be Bald, but in the second generation there will again be found both bald and bearded forms. Mendel showed that where simple characters, such as those now under consideration, are involved, the individuals in the second generation fall unto two main groups, one group representing the character of the recessive parent and the other similar to or approximating the dominant one. Those resembling the former parent represent about 25% of the whole number. These breed true in succeeding generations. Of the second group, which represents 75% of the whole, ⅓ will produce true dominants while the remaining ⅔ will again divide or segregate in the next generation producing the same constant and inconstant forms. This fact of segregation is one of the essential discoveries in Mendel's law.

The proportions which are obtained when two sorts possessing simple alterating characters are crossed (monohybrid combination) may be represented as follows:—



It will be seen from the above that the inconstant Bald forms segregate in each generation into 75% Bald and 25% Bearded, or in the proportions 3:1.

Mendel has given a simple and interesting explanation of his famous law, a knowledge of which is essential to a proper understanding of the work at Svalöf, as indeed of that at most other breeding centres of the present day. This explanation may be presented substantially as follows:—

In the higher plants and animals reproduction takes place as a result of a union between two sexual cells (gametes), viz.—a male and female cell. Each gamete which is concerned in the origin of a given variety or species possesses a definite *factor* for each of the characters by which such variety or species is distinguished. Thus in the case of a red flowered variety of plant, the gametes which are responsible for its being, possessed a factor for red color. Similarly, a constant tall sort has a gamete with the factor for tallness. A low growing form has a gamete with the factor for low growth, etc. Now when a crossing is effected between say a black-kernelled and a white-kernelled sort, a "black" gamete unites with a "white" gamete with the result that a hybrid is produced which is black or dark brownish. This is due to the fact that "black" is *dominant* over "white." When this dark hybrid individual itself develops gametes, these do not possess the factor for black or brown only, but rather a certain proportion of them possess the factor for black and a certain proportion the factor for white.

This segregation, or division, concerns both the female cell (egg-cell) and the male cell (sperm cell) so that 50% of each kind of cell possess the factor for black and the other 50% the factor for white.

When fertilization takes place between the gametes (egg and sperm cells) of the same plant, as they usually do in self-fertilizating species, there are four different combinations possible, thus:

	Egg-cell.		*Sperm-cell.*	*Progeny.*
1.	Black	×	Black	Black
2.	Black	×	White	Brown
3.	White	×	Black	Brown
4.	White	×	White	White

From the above it will be seen that should all possible combinations be effected and should the black and white gametes be present in like numbers the progeny (second generation, F_2) shall consist of individuals ¼ of which are black, ½ brown and ¼ white. If the black and brown are thrown together into a single group there will be established the proportions 3 black-brown; 1 white.

Nilsson-Ehle (56 p. 6) explains the above principle in the following graphical manner:—

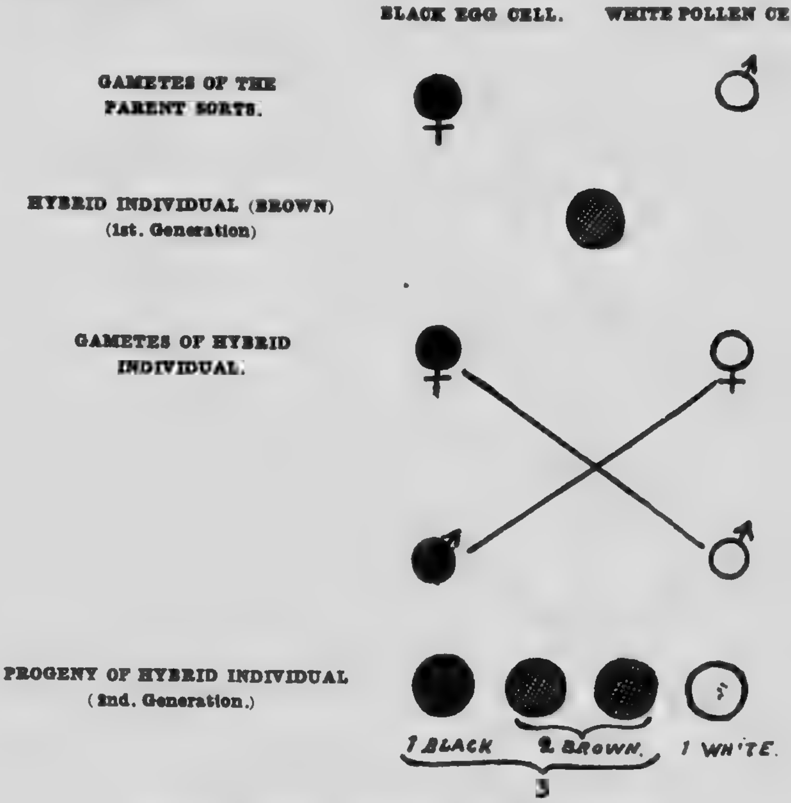

BLACK EGG CELL.
WHITE POLLEN CELL.
GAMETES OF THE PARENT SORTS.
HYBRID INDIVIDUAL (BROWN)
(1st. Generation)
GAMETES OF HYBRID INDIVIDUAL.
PROGENY OF HYBRID INDIVIDUAL
(2nd. Generation.)
1 BLACK
2 BROWN.
1 WH'TE.
3

Fig. IX.—Graphic explanation of the Law of Mendel.

Those individuals belonging to the progeny of the above hybrid wh have originated as a result of a union of two black or two white game (homozygotic individuals) can produce only black and white gametes spectively, and their progeny in each case will be constant in succeedi generations. Those individuals on the other hand, which have been p duced by the union of *unlike* gametes (heterozygotic individuals) such black *and* white, for example, will in turn produce *both* black and whi gametes and the progeny will therefore display the same "variation" as th shown in the original crossing.

When more than one character pair is involved the result is somewh more complicated yet in full accord with the leading principle. If, f example, a *Bald Lax-eared* wheat is crossed with a *Bearded Dense eared* so (dihybrid combination,) there are two character pairs to be dealt with, instea of one. These may be represented as follows:—

Biffen (8) has shown that the first generation hybrids (F_1) from crosses between sorts having the above characters differ according to the varieties used. They are Bald or nearly so and lax-eared or strongly inclined in this direction. *Baldness* and *Laxness* are here the dominant characters and hence only Bald and Lax-eared forms appear in the first generation. In the second generation hybrids there will be shown different combinations of the potentialities of the parents arising through a union of egg-cells and pollen-cells. Considering the two character pairs in question there may be four kinds of egg-cells involved in the union, namely egg cells combining the potentialities of *Bald and lax-eared types, Bald and dense eared types, Bearded and dense-eared and Bearded and lax-eared.* The same combinations are possible in the formation of the sperm or pollen cell. When these four kinds of egg-cells and four kinds of pollen cells are brought together, 16 combinations are possible. These may be shown in the following manner allowing *B* to represent the Bald character, *b* the bearded, *L* the lax and *l* the dense: (F_2=second generation; F_3=third generation or progeny of F_2).

Description of progeny of F_2.

♀ ♂

B L × B L = Bald and Lax forms.
" × B l = Bald and Lax (+ dense)
" × b L = " " " (+ bearded)
" × b l = " " " (+ bearded and dense)
B l × B L = Bald and Lax (+ dense)
" × *B* l = Bald and dense
" × b L = Bald and Lax (+ dense and bearded)
" × b l = Bald and dense (+ bearded)

b L × B L = Bald and Lax (+ bearded)
" × B l = Bald and Lax (+ bearded and dense)
" × b L = Bearded and Lax
" × b l = Bearded and Lax (+ dense)
b l × B L = Bald and Lax (+ bearded and dense)
" × B l = Bald and dense (+ bearded)
" × b L = Bearded and Lax (+ dense)
" × b l = Bearded and dense.

Without regard to whether the above combinations are constant or inconstant we find 9 which have both of the Dominant characters, viz.: *Baldness* and *Laxness*, 3 and 3 with either of the Dominants and either of the Recessives and 1 with both Recessives, making in all the 16 combinations indicated. These combinations and proportions may be expressed concisely as follows:—

$$9\,B\,L + 3\,B\,l + 3\,b\,L + 1\,b\,l = 16.$$

These are the normal combinations and proportions which may be expected in an ordinary dihybrid crossing when simple alternating characters are involved.

That the segregation of the progeny in the second generation of dihybrid crossings actually takes place in the above manner and gives results which correspond very closely with what might be theoretically expected has been shown by numerous investigators working in widely different fields. A good example is afforded by Tedin (72, p. 158) in crossings with pease. In two of the sorts the two dominant characters were *red color* of flower and *black hilum*, while the two recessive characters were *white flower* and *light colored hilum*. In a third crossing the two dominant characters were yellowness and roundness of seeds, while the recessive characters were greenness and angularity of seeds. The characters of the parents together with the actual combinations and proportions into which the second generation divided themselves is shown as follows:—

Characters of Parents.

	Dominant Characters	*Recessive Characters*
Crossing Nos. I. & II.	A (Red flowers) B (Black hilum)	a (white flowers) b (light hilum)
Crossing No. III.	A (Yellow seed) B (Round seed)	a (green seed) b (angular seed)

VISIBLE CHARACTERS SHOWN IN SECOND GENERATION HYBRIDS.

		A B		*A b*		*a B*		*a b*
Crossing No. I.	Number	221		78		71		25
	Relation	9	:	3·2	:	2·9	:	1
Crossing No. II.	Number	250		87		82		33
	Relation	9	:	3·1	:	3·0	:	1·2
Crossing No. III.	Number	1342		445		513		168
	Relation	9	:	3·0	:	3·4	:	1·1

The above proportions, it will be noted, correspond very closely w
what might be theoretically expected, viz., the proportions 9 : 3 : 3 : 1.

As has already been pointed out in this paper, the number of possi
combinations is increased immensely, the greater the number of differe
tiating characters involved in the crossing. The proportions, in normal cas
at least, agree with the same law as that which governs the union in mon
hybrid and dihybrid combinations.

From the above elucidation of the Law of Mendel there emerges t
two essential discoveries of that law, one of which indeed may be said to b
complementary of the other. These are as follow:—

(a) The different characters behave as units and, during the process o
reproduction, segregate and are carried over from one generation to anothe
without undergoing any essential change.

(b) The different characters act independently of each other by reaso
of which fact many different combinations may be effected by differen
groupings of a relatively small number of units.

Thus has the Mendelian annunciation thrown an entirely new light o
the nature of hereditary variations and has introduced quite a *new principl*
into biological science.

In establishing his law of hybrids, Mendel wisely enough worked with simple differentiating characters, and it was upon the behaviour of these that he framed his law. At the same time he premised that complications would doubtless occur which would require a further exploitation of the principles involved to explain. These complications have come and have been met by various workers. To some they have been discouraging and confusing; to others they have served as a stimulant to further investigation and study. Crossing work in great extension has therefore been prosecuted and the progeny studied with extreme care. In this way the unit constitution of many sorts used as parents has been determined. This knowledge has served not only to elucidate some of the apparent irregularities in, or exceptions to, the Mendelian annunciation, but also seems to offer an explanation of the appearance of many of the *strange forms* in our cultivated crops which indeed is our chief concern just now.

A direct outcome of these investigations has been the establishing of two new theories which may be regarded simply as further developments or modifications of the Law of Mendel, as that law was first described. The law itself is in no way altered by these developments; it is only shown to be applicable to complex as well as to simple problems. The first of these theories is known as the *Theory of Presence and Absence* and implies that the "Presence" of a certain unit or character with its corresponding "Absence" together form, paradoxical though it may seem, a character pair. This idea was first applied to plant life by Correns as a result of many years of most exacting work, although Bateson, Punnett and E. R. Saunders were the first to fully recognize the principle and to develop it as a new and consistent theory.

The Theory of "Presence and Absence."

This theory will be better understood when we remember that Mendel considered there to be in the gamete a definite *something* corresponding to the dominant character or a definite *something* corresponding to the recessive character. In no case, however, could these coexist in a single gamete. For these *somethings* the term *Factor* has come to be commonly used.

Mendel believed that the gamete always carried a definite factor corresponding to either the dominant character or the recessive character of a character-pair. No gamete however, could carry more than one of the two factors belonging to such a pair, by reason of which fact the characters were said to be alternative to each other. This conception has undergone a slight modification within recent years owing to the number of cases which it was unable to explain. This difficulty was met in a simple way by the theory of *Presence and Absence.*

Some excellent illustrations of the manner in which this theory may be applied, together with the difficulties which it seems to elucidate, are afforded by Nilsson-Ehle in crossings between different sorts of oats and wheat. Thus in crossings between certain black and yellow-grained oat sorts, *white-kernelled individuals appeared regularly in the second generation.* According to ideas which prevailed before exact experimental data were available, these white grained forms would be regarded either as 'reversions' to the character of a former parent, to the sudden reappearance of a previously latent character or perhaps to something quite *new.* Not only did new forms arise in these crossings but the proportions into which the hybrids grouped themselves showed that the combination was not a simple monohybrid one.

A concrete example is afforded in the crossing made at Svalöf between the yellow-grained oat sort *No. 0375* and the Black sort *No. 0401* (49 p. 44). In the second generation there were found in one case 155 Black grained plants, 43 yellow-yellowish and 15 white or in the proportion of 10.3 black; 2.9 yellow-yellowish; 1 white. By grouping the yellow and white grained forms together we have the proportions 2.7 black; 1 yellow-white. Of the above 213 plants, 185 were reasonably well developed. When the seed of the latter came to be sown out in separate plots there were obtained the following:—

5	plots	produced constant black-kernelled plants.
20	"	showed a mixture of black and yellow kernelled plants.
45	"	showed a mixture of black, yellow and white kernelled pl
2[illegible]	"	showed a mixture of black and white kernelled plants.
[illegible]	"	produced constant yellow-kernelled plants.
2[illegible]	"	showed a mixture of yellow and white kernelled plants.
15	"	produced constant white-kernelled plants.
[illegible]		

[illegible] in question was therefore clearly enough a dihybrid since [illegible] contained only black and white-kernelled forms and ot only black and yellow.

In the light of the *Theory of Presence and Absence* this stra phenomenon [illegible] planation. Instead of *Black* and *Yellow* fo ing [illegible] each of these acts independently of the oth *Black* [illegible] black forming one pair and *Yellow* with the *abse of yellow* forming [illegible] pair. This crossing may be illustrated follows:—

B (black) × b (absence of black)

y (absence of yellow) Y (yellow)

"On this theory," says Punnett (55 p. 35) "the dominant character of a alternative pair owes its dominance to the presence of a factor, which is abse in the recessive."

The Black oat is therefore black owing to the fact that it possesses factor for "blackness" which is absent in the recessive. Instead of the gamet always carrying a definite factor for either dominance or recessiveness it ma be regarded as either possessing or not possessing one of the factors of a alternative pair; in other words the factor is either *Present* or *Absent*. Thi conception will become clearer if we follow its application in detail to th case of the above crossing. In this case the presence of each of the tw factors Black (B) and Yellow (Y) is alternative to its respective absence The Black-grained oat contains a factor for Black but not a factor for yellow while in a similar manner the Yellow-grained oat contains the factor fo yellow but not that for Black. In the above scheme the absence of Black and Yellow has been indicated by a small "b" and "y" respectively for the sake of convenience.

As already indicated (See page 54) when two character pairs are involved in a crossing as in the above case, there may arise in the hybrids four kinds of egg-cells and four kinds of pollen cells. Either the egg-cells or pollen cells may be represented as follows:—BY, By, bY, by. If the four different kinds of egg-cells unite in all possible ways with the four different kinds of pollen cells involved in the above crossing sixteen different combinations are possible. These may be represented symbolically as follow:—

	F_2	F_3
B Y × B Y =	Black (+ Yellow but yellow hidden)	Constant B
" × B y =	Black (+ yellowish)	Constant B.
" × b Y =	Black (+ yellow)	3 B: 1 y.
" × b y =	Black (+ yellowish)	12 B: 3 y. 1 w
B y × B Y =	Black (+ yellowish)	Constant B.
" × B y =	Black (pure)	Constant B.
" × b y =	Black (+ yellow)	12 B, 3 y: 1 w.
" × b y =	Black.	3 B.; 1 w.
b Y × B Y =	Black (+ yellow)	3 B; 1 w.
" × B y =	Black (+ yellowish)	12 B. 3 y. 1 w.
" × b Y =	Yellow	Constant Y.
" × b y =	Yellowish	3 Y; 1 w.
b y × B Y =	Black (+ yellowish)	12 B: 3 Y. 1 w.
" × B y =	Black	3 B., 1 w.
" × b Y =	Yellowish	3 Y; 1 w.
" × b y =	White	Constant W.

F_2: 12 B; 3 Y.—Yellowish; 1 white.

Twelve out of the 16 zygotes contain "B" but not "Y" and are thus pure Blacks. Three contain "Y" but not "B" and are thus pure Yellow. Nine contain "B" and "Y," but since "B" is dominant over "Y" they are all Black or Blackish. Finally one contains neither Black nor Yellow, and is White. The above scheme illustrates clearly the manner in which new and strange forms may arise either under domestication or in nature.

When the white-kernelled sort No. *0315* was crossed with the *Black Moss* variety (No. 0670), there were obtained not only Blacks and Whites but *Greys* as well. The proportions obtained moreover corresponded with those peculiar to a dihybrid combination. The actual proportion in this case was 187 black, 38 grey and 17 white, or 11 black, 2.2 grey, 1 white (49, p. 25). The assumption here is that this particular sort possesses not only a unit for Black color but also a unit for grey, although the grey is hidden until brought into certain combinations when it appears as a new character. The following dihybrid scheme is submitted as explaining the situation:—

Sort No. *0315* ♀ (white)   Sort No. *0670* ♂ (black)

(absence of black) b   B (Presence of Black)

(absence of grey) g   G (Presence of Grey)

Here we have represented four possible combinations which may go to form four different kinds of pollen cells and four of egg-cells, viz.: *b G*, *b g*, *B G*, *B g*. When these four kinds of pollen cells and four kinds of egg-cells are brought together the sixteen combinations peculiar to a dihybrid crossing are made, the combinations b G × b G, b G × b g and b g × b G representing the "new" grey forms.

When the black sort *Moss* (0670) which, as we have seen, appar possessed a unit for Grey as well as a unit for Black, was crossed with yellow sort *Gold Rain* (0386) there were obtained in the second genera *Blacks*, *Yellows*, *Greys* and *Whites*, the two latter representing apparently c new forms (49, p. 48). The proportions of the different forms of hyb obtained showed furthermore, that the crossing had been a *trihybrid* one is, three character pairs had been involved. These may be represented in following scheme:—

Gold Rain	*Moss*
b (absence of black)	B (Black)
g (absence of grey)	G (Grey)
Y (Yellow)	y (absence of yellow)

The gametes (sexual cells) formed in this case are of eight kinds, v *B G Y*, *B G y*, *B g Y*, *b G Y*, *B g y*, *b G Y*, *b g Y*, *b g y*.

In the second generation the progeny of four individual plants from were grown in separate cultures and gave the following results:—

(a)	F_2	116	Black,	22	Grey,	5	yellow-yellowish,	2	Grey and yellow,	10	Whi
(b)	"	54	"	11	"	9	"	2	" "	3	"
(c)	"	29	"	6	"	3	"	0	" "	4	"
(d)	"	59	"	14	"	3	"	1	" "	5	"
Total		258	"	53	"	20	"	5	" "	22	"

The theory that certain characters may possess more than one unit, each of which has the same external effect.

The *second theory*, or modification of the Mendelian theory, to whic reference has already been made as seeming to contribute to a better unde standing of the origin of hereditary gradations and to the occurrence c aberrant types, has been advanced by Nilsson-Ehle (46 and 49) in connec tion with work with cereal grains, and by East (11) of the United States c America, with Maize. This theory assumes that a *certain character may con sist of more than one unit, each unit having practically the same external effec* Thus it has been observed that a black-kernelled oat sort may possess mor than one unit for Black, each unit alone being able to produce the typica black colour. A good example is afforded in the crossing between the blacl sort *0668* and *Ligowo*, 0353 (white). The former sort has been found or analysis to contain *two independent units for Black* (B_1, B_2) and also a unit for Grey (G), all of which are apparently absent in the sort *0353*. The constitution of these sorts is represented in the following manner:—

0668, B_1 B_2 G.
0353, b_1 b_2 g.

This crossing is therefore a trihybrid one instead of the simple monohybrid, although the latter might reasonably be expected in the absence of any exact knowledge as to the inner constitution of the sorts involved.

Another interesting example of color character consisting of more than one unit was discovered in connection with a crossing between the white-kernelled wheat sort *Pudel* (See Fig. 12) and *0700*, a pedigree sort out of the common red-kernelled *Swedish Velvet chaff* (44, p. 268). The kernels in F_1 of this crossing are Red, as Red is dominant over White; in F_2 the ratio 63 Red: 1 White was produced. This fact, together with results obtained in later generations indicates that three character pairs must have been concerned in this crossing. It is therefore assumed that the Red Color character possesses *three* units for Red which, with the corresponding absence of the same units, constitute three character pairs as follows:—

Red	*White*
R_1 R_2 R_3	r_1 r_2 r_3

Crossings between sorts which are apparently identical in regard to the characters considered.

Two Red-kernelled wheat sorts No. *0234* (pure line from a Squarehead variety) and *0406* (Svalöf's Bore wheat), which are very similar in respect of color of kernel, were crossed at Svalöf in 1907 (54, p. 66). F_1 was red kernelled, while F_2 gave 52 red kernelled and 5 white kernelled individuals = 10.4 Red: 1 white. All the 57 F_2 individuals were sown out in separate cultures and gave the following results:—

25 constant Red.
13 segregating in the proportion 15 Red: 1 White.
14 " " " 3 Red: 1 White.
5 constant White.
—
Total 57

These results indicate that each of the parents has its own peculiar unit for Red Color. These two units with their corresponding absence in the opposite parent, constitute two character pairs. The crossing may therefore be expressed as follows:—

0406		*0234*
(Red)		(Red)

$$\begin{array}{ccc} R_1 & & r_1 \\ | & \times & | \\ r_2 & & R_2 \end{array}$$

According to the above scheme one of the combinations in F_2 will lack both color units = (r_1, r_2) and consequently will be white-kernelled.

The results actually obtained in the above case may be compared
the theoretical expectation from a dihybrid crossing as follows:—

Results obtained.		*Theoretical expecta*
Constant Red	25 = 7·0	9
Segregating Red and White	13 = 3·7	3
" " " "	14 = 3·9	3
Constant White	5 = 1·4	1

When two wheat sorts having about the same average head den were crossed, there were produced combinations having *greater density t either parent*. Thus, when the sorts *Bore* and *Extra Squarehead* (See Fig. having an average density of 32·8 and 34·6 respectively, were cross combinations averaging in head density as high as 39·1 were produc Heads which were more open in character were also produced, so that progeny may be said to have exceeded the limits of density of the pare in both directions (44 p. 282).

When two sorts having about the same average length of straw w crossed, there arose hereditary forms which were both longer and shor than either parents.

Similar results were obtained when certain oat sorts having about t same average length of hull or glume were crossed, forms which were long and others which were shorter than either of the parents being produce A good example is found in the crossing between *Hvitling* (0301) and *Du pauer* (0926) (44 p. 286–7). The average length of the hull of these sor is 16.7 and 16.4 m.m. respectively. Among the progeny of the hybri there were isolated forms measuring, in the F_3 generation, as low as 14 m.m. and as high as 18.6 m.m., while the same differences were shown t following year (F_4). Between these extremes there were also found nume ous hereditary gradations. An interesting fact revealed by these crossin is that differences in the length of hull may be produced without effecti in any way the length of the kernel. This is a good example of the inde pendent nature of different characters.

When the two Svalöf oat sorts *Bell No. II* and *Great Mogul* were crosse a number of combinations of the side-panicle type were produced althoug both parent sorts belong to the spreading-panicle class. The assumptio here is that each parent possesses its own peculiar unit for spreading panic viz. A_1 and A_2 respectively. The *presence* of these two units together wit their corresponding *absence*, constitutes two character-pairs, which may b represented in the following manner:—

$$\begin{array}{ccc} \textit{Bell II.} & & \textit{Great Mogul.} \\ A_1 & & a_1 \\ | & \times & | \\ a_2 & & A_2 \end{array}$$

Those combinations which lack both of the units for spreading panicle — (a_1, a_2) will be side-panicled. In the above manner may be explained the "sudden appearance" of a side-oat type in a variety which normally produces a spreading panicle.

Rust resistance in wheat.

Some very interesting and significant results have followed investigations at Svalöf into the inheritance of resistance against yellow rust (*Puccinia glumarum*) in wheat (52). As is well known, different sorts and lines of wheat differ considerably in their attitude toward this disease. Some are relatively resistant although not absolutely immune; others possess a low degree of resistance. Between the two extremes again are to be found sorts possessing a varying degree of resistance. Eriksson and Henning recognize five grades of rust (0–4) and according to Nilsson-Ehle (52 p. 59) a few more classes may still be added. Thus *Extra Squarehead II* and *Kotte* are classified under class *o*, being most resistant; in the second, relatively resistant class, is placed *Grenadier;* in the third, possessing a lower degree of resistance, belongs *Pudel*, while in the fourth and most susceptible class, the sort *Top Squarehead* constitutes a prominent representative. The degree of rust resistance possessed by a given sort is found to be relatively constant from year to year.

From the crossing between the sorts *0401* × *0705*, both classified as Grade 2, eight separate cultures were investigated during the bad rust year, 1904. The difference between these plots in regard to their attitude toward rust is recorded as "exceedingly striking." The difference between the most susceptible culture and that which showed greatest resistance was much greater than the difference between the parents themselves. Thus plots 2, 5 and 6 were more severely attacked than were either of the parents, while plots 7 and 8 showed somewhat greater resistance than did the parents.

From the crossing *0319* × *0501* (both sorts of high resistance) there were produced a number of lines some of which, in F_3 proved much more susceptible than either parent. Similarly, in the crossing between *0315* (grade 1) and *Swedish Velvet Chaff* (very resistant) 2 plots out of a total of 96 in F_3 proved extremely susceptible, being classed as grade 5, despite the fact that the year was not a particularly bad one for rust.

It will thus be seen that apparently new forms may arise from crossings between sorts which to all appearances are practically *identical* in regard to certain characters. The origin of these forms is due simply to the peculiar grouping of definite units already in existence and not to the acquisition of anything actually 'new.' In other words, they constitute different gradations—a *quantitative hereditary variation*—the different gradations being "continuous." This fact at once suggests the necessity of making a clear distinction between outer visible characters and inner factors.

Crossings between sorts which differ in regard to certain characters.

When wheat sorts of which the average head density is *different* have
crossed, it has been found in some cases that extremes, which appear to
quite new forms, arise. An example is given by Nilsson-Ehle (52 p. 279-
in the crossing of an autumn wheat (*Triticum compactum*) having a h
density of 55, with Grenadier (*T. Vulgare*) having a head density of 32. In
second generation there were found 10 forms out of a total of 42, hav
a head density of fron. 18 to 21. Such heads were of course very long
open and appeared distinctly different from either parent. Conversely,
crossing one of these open-headed individuals with another variety possess
about the same degree of head density, compactum types may be produc
The appearance of such forms is not attributed to so-called 'reversion' or
'mutation' but simply to a peculiar combination of already existing units.

The fact that head density, or length of the internode in heads, is a Me
delian character is further amplified by Nilsson-Ehle (52 p. 26-56) in co
nection with crossings recently described in detail. In all of these crossin
the compact headed *T. Compactum* (Schwed. Binkelweizen) was one of t
parents, the other parents possessing heads of from average to low density

One of the most interesting of these crosses was *T. Compactum* × *Pu*
(See Figs. X-XII) the latter sort possessing a head of average density. T
result of this crossing (in line B.) was as follows:—

F_1: Compactum.

F_2: Segregating into 61 genuine compactum (of which number 5 we
decidedly more compact than either of the parent sorts); 5 somewha
more outdrawn-compactum; 28 of the foregoing group sharpl
defined as average to more open head than either parent (=2.
Compactum: 1 not-compactum).

The seed of all of the 94 F_2 plants was sown out in separate row
with the following results:—

5 compactum: very dense F_3: 5 constant compactum
56 " F_3 { 18 " "
38 segregating into compactum and 'not-compactum.'
5 somewhat more outdrawn compactum F_3: 5 segregating into compactum and 'not-compactum.'
28 'not-compactum' F_3. . . . . All the progeny obtained in inheritance the "*not-compactum*" character.

Of the 23 constant compactum individuals 5 were decidedly more
dense than the others. Three of these retained this exceptional density
while the other 2 again assumed the average condition of the lot. Of the
remaining 18 of the constant compactum individuals, 2 proved especially
dense.

A significant conclusion arrived at by Nilsson-Ehle as a result of the behaviour of certain crossings in which *Compactum* was concerned, is that this sort possesses a special so-called '*inhibiting*' factor which is absent in the other sorts with which it was crossed. This factor, he believes, is largely responsible for the extreme shortness of the internodes of this type. Thus the Compactum form used in the above crossings is regarded as being in reality a "*land*" wheat (common open-headed wheat of the country) its compactness being due to the presence of a certain definite factor. When a *Compactum* of this constitution is crossed with a *Squarehead* sort, the crossing behaves quite in the same manner as when a *visibly* open-headed *Land* wheat is crossed with *Squarehead*, or some other sort of average head-density.

In crossings between *Swedish "Land" wheat* and *Squarehead*, the long, open type of the former is found to be dominant. In the F_2 generation this type is therefore in the majority. By crossing *Compactum* and *Squarehead*, the long open type again prevails instead of *Squarehead*. When the Compactum factor is designated at C and the "lengthening" factor possessed by the open headed *Land* wheat as L the crossing may be represented by the following scheme:—

$$\begin{array}{ccc} \textit{Compactum} & & \textit{Squarehead} \\ C\,L & \times & c\,l \end{array}$$

$$F_2\text{: Ratio } \underbrace{9CL : 3\,C\,l}_{12\text{ Compactum}} : \underbrace{\underbrace{3\,c\,L : 1\,c\,l}_{4\text{ “not-compactum”}}}_{3\text{ “land” wheat}:\ 1\text{ Squarehead}}$$

That the character of the head of "land" wheat is actually distinguished from Squarehead by two or more factors seems clear.

Referring again to the crossing *Compactum* × *Pudel*, line B, of the 28 F_3 plants belonging to the "*not-Compactum*" group, only 2 approached the average head density of *Pudel* while the remaining heads were longer. This approximates closely the proportion 15: 1 which would be expected if *Compactum* possessed two 'lengthening' factors which were absent in Pudel, a situation which is regarded by Nilsson-Ehle, after a very careful analysis, to be the case. These two "lengthening" factors he designates as L_1, L_2 each of which may act independently of the other and which in combination may produce longer internodes than those possessed even by *Pudel*.

This crossing is expressed in the following manner:—

$$\begin{array}{ccc} \textit{Compactum} & & \textit{Pudel} \\ C\,L_1\,L_2 & \times & c\,l_1\,l_2 \end{array}$$

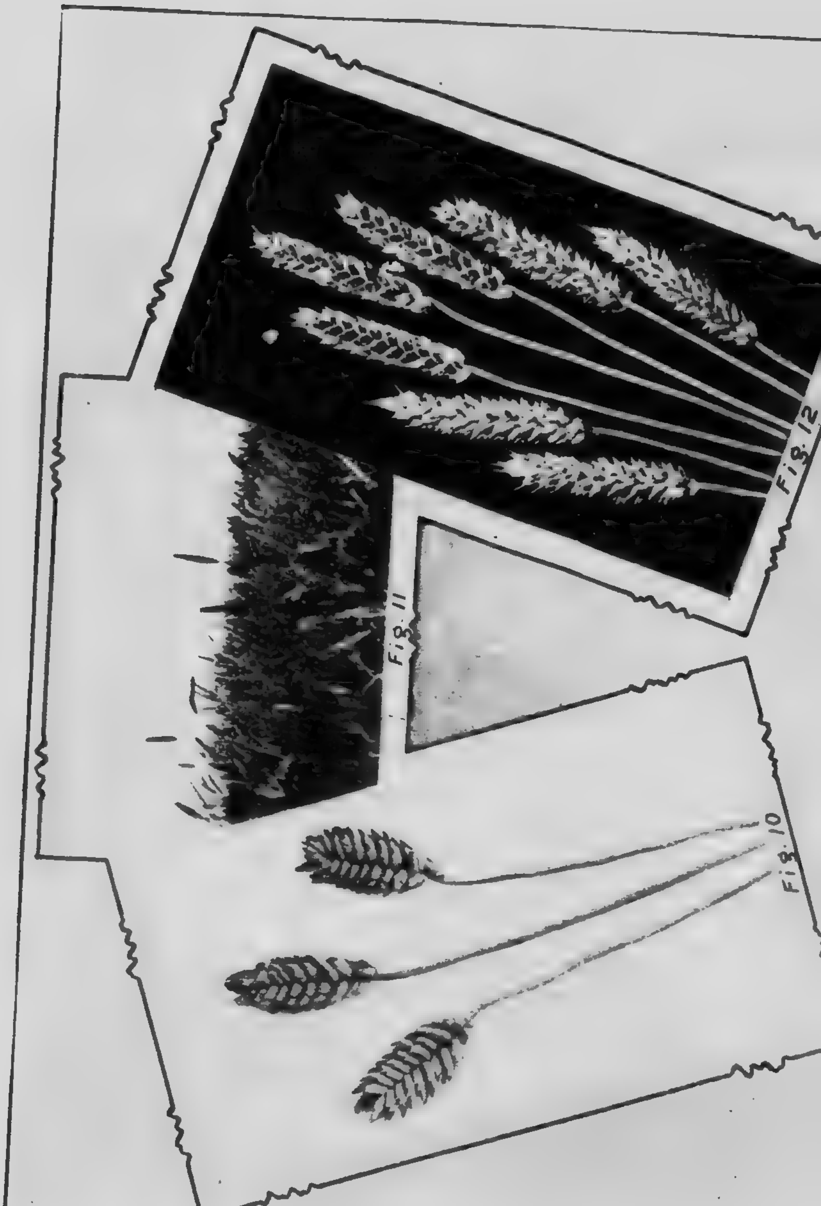


Fig. 12
Fig. 11
Fig. 10

The combinations which are theoretically possible when sorts of this constitution are crossed, include all the different types which have actually been found by the above author to arise in practice. Thus, four of the above combinations ($L_1\ l_2 \times l_1\ l_2$; $l_1\ l_2 \times L_1\ l_2$; $l_1\ L_2 \times l_1\ l_2$; and $l_1\ l_2 \times l_1\ L_2$) should give a simple 3: 1 proportion i.e., three long-headed types to 1 Pudel type. Four combinations should give 15 long-headed forms to 1 form approximating the type of *Pudel*: seven combinations should give only long-headed forms (*longer and more open-headed than Pudel*) and these should represent the longest heads of all produced in this crossing, which also was found to be the case.

The assumption that two 'lengthening' factors are possessed by *Compactum* seems, from the above and other crossings which might be cited, to be quite justified. It is also believed probable that in addition to these two distinct factors which account for the sharp segregation of characters, others may exist which produce a secondary or bi-segregation—"Nebenspaltung" That such segregation may obtain in connection with other characters involved in a given crossing is believed both by Tedin and Nilsson-Ehle as well as by other investigators to be the case.

In crossing *Compactum* ($C\ L_1\ L_2$) with a *Land* wheat of the constitution $c\ L_1\ L_2$ the segregation must naturally be the simple 3 *Compactum*: 1 *Land* when *Compactum* is dominant. When, on the other hand, a *Compactum* of the Constitution $C\ l_1\ l_2$ is crossed with a *Land* wheat $c\ L_1\ L_2$ then must arise forms of the Constitution $c\ l_1\ l_2$ (Squarehead type) as "new" entities. This would seem to explain the frequency with which Squarehead types arise out of crossings between certain Compactum and "Land" types, the appearance of *Squarehead* being due simply to a *new combination* of units already in existence.

From the crossing *Compactum* ($C\ L_1\ L_2$) × Squarehead ($c\ l_1\ l_2$) there must arise the 'new' combination $C\ l_1\ l_2$ which lacks both 'lengthening' factors and which must therefore possess shorter internodes than the parent $C\ L_1\ L_2$ (*Compactum*).

From the above investigation there emerges the one outstanding observation that the Compactum factor C in the Compactum sort used in the crossings in question, restrains or "inhibits" the L factors so that $C\ L_1\ L_2$ and $C\ l_1\ l_2$ may in outward appearance resemble the genuine Compactum. While it is not believed that the effect of the L factor is completely suppressed by the presence of C, it is thought to be very greatly reduced.

Of all the different sorts used as parents in these investigations only *T. Compactum* (Type I), proved sufficiently well defined and constant in character to enable it to be fairly recognized as a distinct type. The gradations between the types which came next in denseness—Types II and III, (under which the Squareheads are classed)—and the extremely open headed "Land" wheat (Type VII) was found to be so gradual and the lines of demarkation between them so confused by fluctuating modifications, that it was quite impossible to group them into sharply defined types as was attempted at Svalöf at an earlier date. Any grouping of types which may be attempted must therefore be a purely artificial one.

In crossings made between sorts which are susceptible to yello and those which are relatively resistant a whole line of hereditary grad between the extremes may be produced (52, p. 57-75). Thus in the ing *0203*, Extra Squarehead (very resistant) × *0406*, Bore (suscep there were found in the third generation only 2 plots out of a total of which the susceptibility was about as great as *0406* (Grade 4); the were intermediate, or more or less resistant (Grade 0).

An exceptionally large number of hereditary gradations, in rega rust resistance, was produced by the crossing *0406* (Bore) × *0728*. The grade of the parents together with that of different lines in F_4 is giv follows:—

0406 . .		11/6 Rust, Grade 4
0728		" " " 2
0406 × 0728 F_3 —	6 plots	" " " 0
	6 "	" " " 1
"	6 "	" " " 2
	2 "	" " " 3
	3 "	" " " 4
	3 "	" " " 5
	2 "	" " " 6

That lines were produced which were both *more and less resistant t either parent* is clearly shown.

When the very resistant sort *0319* (Kotte) was crossed with the *0501* (Grenadier) which possessed an average degree of resistance, lines w produced which, in F_3 were much worse attacked (Grade 2-4) than was *05* The sort *0319* being free from rust, during the year of investigation, it impossible to judge whether or not combinations were produced which, the average, would be still more resistant than it.

In crossing susceptible and resistant wheat sorts, Nilsson-Ehle clai never to have obtained results which showed the simple monohybrid co bination, but rather was the condition more complex. **Biffen** (9, p. 10 on the other hand, claims that rust resistance follows in segregation, the sim monohybrid rule, viz.:—3 : 1.

Crossings made between late and early oat sorts have also given inte esting and significant results. In no case has Nilsson-Ehle found the resu to show the simple monohybrid combination, but always a more compl condition as in the case of rusts. An example is afforded in the crossi between *0408* (medium early) × *0450* (late):

Result:—Out of 112 plots in the third generation there were:—
(a) 4 plots ripening some days earlier than the earlier parent.
(b) 10 plots ripening decidedly later—5 to 8 days—than the late parent.

The hereditary gradations between the different plots were als numerous.

A further example of both extremes of parental characters in regard to earliness being exceeded, was met with at Svalöf by the writer during the summer of 1910. Thus, from the crossing between the two Black oat sorts *Roslag* (01006) and *Black Bell II* (0408) there were 26 separate cultures in the third generation. These cultures were numbered from 235 to 260 inclusive. Number 257 was at least three weeks later than the next latest culture, parents included, remaining in the field long after all other sorts had been taken to the barns. This was the most extreme case of this kind on record at the above Institution up to that time. A few of the combinations on the other hand, were somewhat *earlier* than the earlier parent, *Bell II*.

In a crossing between *Triticum Compactum* wheat (very winter hardy) and a less hardy sort, there were produced forms which were completely winter killed in the 2nd generation, and others which proved quite hardy. None, however, proved so hardy as *T. Compactum*, but were at best only intermediate. Other crosses have shown similar complex results and it is, therefore, believed that Winter-hardiness is not a simple character, but rather is one which, like other quantitative characters previously referred to, depends on different units or factors. Not only do the experimental evidences seem to support this view, but physiological considerations also lead to the same conclusion, as Johannsen (17 p. 175) has recently pointed out.

Investigations at Svalöf have shown further that certain units produce only visible effects when combined with certain other units. The result of such a combination is to strengthen or enhance the visible effect of one or the other of the units involved. Thus has Tedin found on crossing certain red-flowered and certain white-flowered varieties of pease that the resulting combinations produced flowers having a Red Violet color. Numerous experiments have led to the conclusion that the white sort possesses a unit or factor which alone produces no visible effect, but when brought into combination with the factor for rose color produces a *Red Violet*.

Experiments in crossing have therefore shown that the process of segregation is often of a very complex nature, and one in which many units may be involved. Such characters as *winter-hardiness, time of ripening, stiffness of straw* and *resistance against disease*, instead of being simple characters, are believed to be composed of many units or factors by reason of which they are called by Johannsen "*construction characters*." By means of different combinations of the various units, a large number of constant gradations of a quantitative nature may arise, which may differ physiologically as well as morphologically from the parents. These gradations or lines then, are not the expression of 'a natural tendency' to vary, but rather of different combinations ("combinations-variation") which may arise from a relatively small number of initial differentiating units as already explained.

An especially complex character is *yielding power*. This is determined by many different factors such as that for stooling, strength of straw, size of head and kernel, resistance against disease, and finally upon the different units which are concerned in the constitution of each of the characters themselves. It is of special interest that characters of direct practical importance to the plant breeder behave in the manner indicated.

The Origin of Aberrant Forms as "Mutations."

"False Wild Oats."

The appearance in cultivated oat sorts of what has come to be k
in Canada as "False Wild Oats" has been a matter of common observ
in Scandinavia for many years. These aberrant forms have been
both in black and white-grained sorts. Their seeds bear long twiste
bent awns and possess the sucker mouth and hairy callus of the true
species, but in form and shape the kernels correspond with the varie
which they are found, a fact which often provides a means of distin
between them and true wild oats. The plant of "false wild oats"
over, does not correspond with that of the true wild species, but is an
counterpart of the cultivated sort. The plant of true wild oats is us
more luxuriant in growth and more drooping and spreading in habit,
usually stands above the common sorts. The plant rather than the s
is therefore accepted as a safer basis of distinction. The origin of t
forms has long been a matter of speculation. The close similarity betw
their seed and that of the true wild species in respect of awn and suc
mouth development has led to the common belief that some relation
exists between them. On the other hand, the close similarity between
form of the seed and character of plant of the former with that of the c
vated sort in which it is found has led to the conclusion that the comn
cultivated sort is also in some way concerned. That these forms do
arise through crossing with the true wild form is shown by the fact that
latter is not found at Svalöf, neither is it in any case used in artificial cross
work. That false wild oat types might arise through a peculiar combi
tion of units is likewise untenable, since the segregation of the heterozygot
the form usually noted as the first deviation from the cultivated type—alw
displays the simple Mendelian proportions, viz.: 1 : 2 : 1.

Furthermore, false wild oats found in a common side oat, such as *Bl*
Tartarian would, in the second generation, divide into *side* and *branch*
types if they arose as crossings between the above type and the branchi
wild oat type, *Avena fatua.* This they do not do.

Extensive investigations covering several years have been made wi
these forms at Svalöf, the final results of which have only recently been pu
lished (55 p. 1–37). According to these investigations the so-called false wi
oat corresponds more closely to what De Vries defines as a *Retrogressive* mutatio
It will be remembered that the above founder of the mutation theory, d
fined two classes of mutation viz:—*Progressive* or positive and *Retrogressi*
or negative. A progressive mutation according to DeVries owes its existen
to the acquisition a new unit; a retrogressive mutation, on the other han
is supposed to arise through the latency of a unit. Without stopping to di
cuss this theory here, suffice it to say that no undisputed case of progressi
mutation in the sense of DeVries has yet been found at Svalöf. Retrogres
sive mutations representing spontaneous changes from the dominant to th
recessive character of a given Mendelian character pair are believed on th
other hand, to occur occasionally. The occurrence of False Wild Oats i
believed to be due to such a change.

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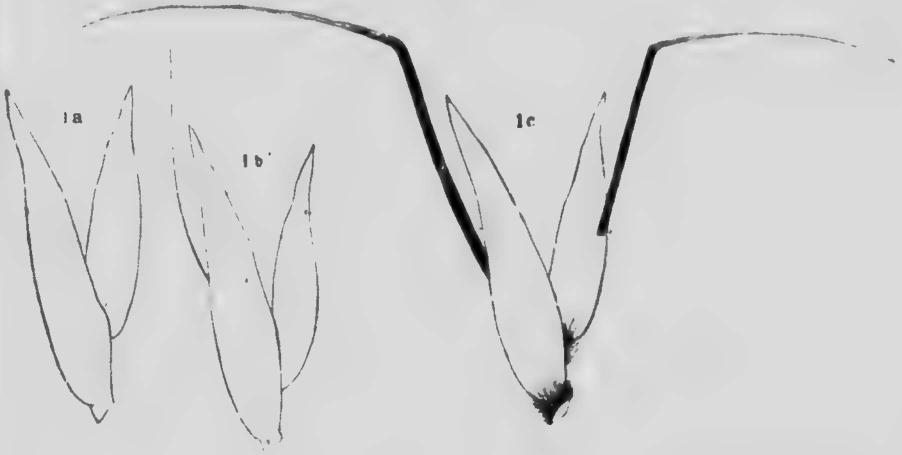
l Oats is

As Hjalmar Nilsson first observed, false wild oats are not completely developed from the beginning. The first year they differ from the cultivated sort only in character of awn. When these first generation types are sown out by themselves they not only reproduce their own peculiar character but produce forms which resemble in character of kernel both the cultivated sort and the true wild species. The experiments continued by Nilsson-Ehle since 1900 have shown that in the production of these forms there is an ordinary segregation in the Mendelian sense, thus proving that mutations act much as do crossings, a fact which often renders it difficult to distinguish between them. In the light of the above observations, the course of development of "false wild oats" is believed to be substantially as follows: Among the ordinary sexual cells arises one which for some unknown reason possesses certain of the wild oat characters. It is believed that the alteration in this cell is due to the dropping out or the lapsing into latency of a restraining or *inhibiting* factor. The absence of the inhibiting factor in both egg and pollen cells allows the typical, fully-developed false wild oat type to arise at once; the presence of these factors in both cells is believed to restrain the development of the characters of the wild oat so that the cultivated form may arise while the presence of such a factor in only *one* of the sexual cells (egg or pollen as the case may be) allows the partially developed form to arise. Returning now to the behaviour of this mutating sexual cell (egg-cell or pollen-cell as the case may be) when fertilized by a normal sexual cell, we find that the result becomes to all intents a crossing between them. It is the F_1 (first generation hybrids) from this crossing (See Fig. 13, b.) which marks the first apparent deviation from the common oat. When the progeny of F_1 are sown, about 25% of the plants produced resemble the typical cultivated sort (Fig. 13 a.) and breed true in succeeding generations. About 50% possess the character of the type first found (Fig. 13 b.). These are in-



Signe Nilsson Ehle del.

Fig. XIII. "False Wild Oats."

constant (heterozygous) and consequently segregate in the next gen
The remaining 25% resemble the characteristic false wild oat type (Fig
These are constant, reproducing true to type in succeeding generatio

From an economic standpoint *False Wild Oats* are not regarded in
navia as being so objectionable as the true species. They are not f
increase materially as they lack those qualities of the true specie
enable the latter to compete so successfully with the cultivated sorts.
reason this plant is ranked as a foreign variety rather than as a weed.

From the above discussion it seems clear that aberrant forms ma
their origin not only through natural crossing but also as a result of
spontaneous changes in sorts which may ordinarily be regarded as co
Up to the present all changes of this nature recorded at Svalöf are b
to be of a *Retrogressive* kind. In no case has a character arisen which w
formerly in existence, and in practical breeding work, it would seem
none need be looked for.

THE NATURE AND CLASSES OF VARIATION (SUMMARY).

The most important conclusions as to the nature and classes of vari
arrived at by Nilsson-Ehle (52, p. 3–19) as a result of his investigation
wheat and oats, are summarized by him substantially as follows: –

1. In classifying the different kinds of variation the only division
can be made is between variations induced by external factors (*mo
tions*) and *hereditary variations*. Both classes, modifications and here
variations, may be either continuous or discontinuous. Hereditary varia
can be quite as "quantitatively continuous" as can modifications and
certain sense quite as fluctuating.

2. The existence of quantitatively continuous, fluctuating, heredi
variation as a 'combinations-variation' has been proven through Mend
analysis in the same manner as has qualitative or discontinuous heredi
variation. Thus one and the same external character such as
color, may be due to the existence of several independent Mendelian fac
or units. It is characteristic for such factors to have practically the s
or at most, a slightly different external effect and in combination with
other actually to produce a *cumulative effect*. In this way the chara
concerned may become *intensified*. These factors may also be in a posi
to alter the external effect of other factors.

Through different combinations of different units a continuous lin
hereditary gradations (continuous hereditary variations) in respect of a gi
character, is brought into existence. In due time the homozygous combi
tions preponderate thus producing a line of constant forms, lines or bioty
These biotypes are therefore not the result of as many 'mutations' but rat
of different combinations of already existing units. In the case of pla
which readily cross-fertilize, an inconstant (heterozygotic) condition is alw
to be expected. In such cases the number of hereditary gradations fro
given number of units will be still more numerous and as a consequence he
ditary variations will appear still more 'continuous.'

3. When forms are crossed which are distinguished by a greater or lesser number of units, the combinations which are possible stand in exact proportion to the number of units involved.

4. While different independent units can produce practically the same external effect and while different combinations can show practically the same external results, cases occur where, from crossings between sorts which externally resemble each other, there arise new combinations with more or less sharply distinct external characters due to a special grouping of the units. In this manner forms which appear as 'new' and which might be mistaken for mutations, can arise.

5. Through continued regrouping of certain factors there may take place what is commonly known as an *acclimitization*. The stronger and more hardy combinations survive while the weaker and less resistant perish in the struggle.*

That continuous hereditary variations do not originate as a result of a relatively limited number of independent units arising through "mutation" as claimed by DeVries, is pointed out by Nilsson-Ehle (l. c. p. 7), who emphasizes the practical importance of a correct understanding of this question. Thus, "in the light of the conception of the existence of a relatively limited number of different Forms or Elementary Species, one would expect to find in old races a relatively small number of characteristic forms, and thus would run the danger of over-looking much valuable material."

The striking constancy of those isolated forms which have been investigated is held responsible in part at least, for the idea that these represent the essential units themselves. The reason for this constancy in self-fertilizing plants has already been explained.

When the hereditary differences between a number of different [illegible] types are investigated and classified, the continuity of hereditary variation is revealed. These differences group themselves around a *mean* in the same manner as do modifications.

In discussing the various terminologies which have been proposed by different writers for the different classes of variation, Baur (3) of Germany points out the confusion which has followed the application of the term *fluctuation* to both modifications and to hereditary variations. The views advanced by this writer are quite in accord with those of Nilsson-Ehle, who has accepted the following general classification, although the difficulty of making sharp distinctions is fully recognized:—

1. Modifications (not hereditary).
2. Hereditary variation.

A distinction is then made between—

(a) Individual, continuous modification and
(b) Individual, continuous variation.

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*This question is discussed more in detail by Nilsson-Ehle in a paper given by him at the International Genetics Conference held in Paris, September 18–23rd, 1911. This paper is entitled "*Acclimatation par recombinaison de facteurs mendeliens.*"

In the case of cross-fertilizing species, where there is a const
grouping of the units producing a continuous fluctuation in quan
characters, a distinction is also made between:—

(a) Fluctuating modifications.

(b) Fluctuating variations.

A final distinction is then made between plus and minus fluctu
thus:—

(a) Plus and minus modifications,

(b) Plus and minus variations.

AN EXPLANATION OF THE OCCURRENCE OF CERTAIN ABERRANT FOR
UNDER DOMESTICATION

Cone wheat.

In the light of the above investigations and conclusions an explan
of the occurrence of certain strikingly aberrant types presents itself.
us consider first the well known case of the *Cone* or "Kotte" wheat (0
which sort was formerly thought to be a "sport" or *mutation*. The o
of this sort is substantially as follows:—In a pure line (0516), which
characterized by long open heads and weak straw there suddenly appe
in 1896, an aberrant form having an exceedingly close Cone-like head a
stiffer straw than the former year. The head density of the sort *0516* is g
in the Record Book as 21, while that of the aberrant type is recorded as
In the records for 1897, the following annotations were made regarding
progeny of the latter form:

"*Great variation, Red White; variations in type of head from Type I*
Type I." In 1898, the following observations were recorded:—"*80% of*
heads with Brown chaff, 20% with White chaff; variations in type of head
prevail." While the data available are still insufficient to permit a safe c
clusion as to whether or not this form, which received the name *Cone* fr
the cone-like type of head, is a mutation, the evidence seems to be agai
such a conception since the progeny showed ordinary segregation of seve
different characters with the production of different combinations in the sa
manner as do artificial crossings.

Re-appearance of dominant heterozygotes in field cultures.

In the velvet-chaffed autumn wheat sort *Pudel*, although this is a pe
gree sort, there regularly appear smooth chaffed forms, often in considera
quantities. An explanation of the appearance of these forms is found
the fact that the sort in question has probably become accidentally cro
fertilized by the pollen of smooth chaffed sorts growing in the Experiment
grounds. The fact that velvet-chaffed sorts are enormously in the minorit
and are surrounded on all sides by sorts which are smooth-chaffed lends su
port to this opinion. This is still further strengthened by the followin
fact —

Velvet chaff being dominant over smooth chaff, the first generation hybrids will be velvet-chaffed, but in the second and succeeding generations both velvet and smooth-chaffed forms will appear. The latter being *recessive* will breed true; the former, or a certain proportion thereof, will continue to segregate into velvet and smooth-chaffed forms. It is therefore a difficult task, requiring several years of careful "rogueing" to get rid of all velvet-chaffed forms.

The persistent reappearance of white-chaffed forms in apparently pure field cultures of brown-chaffed sorts, bearded forms in fields producing bald sorts and white-kernelled forms in red or black sorts also seems capable of explanation, in part at least, as due to the biological difficulty of permanently removing all dominant heterozygotes. Thus, when a white and a black oat sort become crossed, the first generation hybrids are black as *black* is dominant over *white*. In the second and succeeding generations both Black and White grained forms arise. White being recessive the forms possessing this color will breed true; black being dominant, heterozygous forms are concealed which in following generations, divide up into whites and blacks as well as into other forms presenting intermediate shades or gradations of color. Thus will be seen the impossibility of entirely removing white-kernelled forms from an inconstant black-kernelled sort by a single picking out of all white kernels. This is illustrated more clearly in the following diagram which shows what may be expected in each of seven generations from one kilogram (about 30,000 kernels) of a black oat sort of which 128 kernels are heterozygous (41, p. 235).

Black	*Heterozygotes*	*White*
29872	128	
29,904 = 29,872 + 32	64	32 = 32
29,920 = 29,872 + 32 + 16	32	16 + 32 = 48
29,928 = 29,872 + 32 + 16 + 8	16	8 + 16 + 32 = 56
29,932 = 29,872 + 32 + 16 + 8 + 4	8	4 + 8 + 16 + 32 = 60
29,934 = 29,872 + 32 + 16 + 8 + 4 + 2	4	2 + 4 + 8 + 16 + 32 = 62
29,935 = 29,872 + 32 + 16 + 8 + 4 + 2 + 1,	2	1 + 2 + 4 + 8 + 16 + 32 = 63

By the regular Mendelian segregation of the inconstant forms (Heterozygotes) the number of constant white-kernelled forms has increased from 32 to 63 in seven generations. From this time onward the production of such forms will be negligible in so far as the crossing in question is concerned. By continually picking out white-kernelled individuals as they appear, the number is ultimately reduced until practically none remain. A couple of instances may here be given: In the Black sort, *Great Mogul*, there were found from 50 to 125 white + grey kernels per kilogram (30,000 kern different parts of the crop of 1906 at Svalöf from a stock known as “ new stock (C) of this sort was also under cultivation in 1906, and alt all white kernels had been removed from the seed sown, the harvest s from 23 to 29 white kernels in different samples examined. A stock of *Bell* oats which had not been hand picked contained, in 1906 from 3 white kernels per kilogram, while another stock from which all white k had been removed for the two preceeding years produced only from 1 white kernels per kilogram. Hand picking of these sorts has been cont by the Seed Company every year since 1906 with the result that only few white kernels are now found in the commercial sample. In this wa purity of commercial stocks is maintained to such a degree as is po That the occurrence of white-grained oats in black-kernelled sorts is due to spontaneous changes—the dropping out or the lapsing into later a factor for black, in individuals which normally possess this color—ha been pointed out (51, p. 139-156).

In discussing constancy in the color of the grain of oats attenti drawn to modifications (not hereditary differences) which frequently found in black, yellow and grey-kernelled sorts. Black oats from the usually take on a lighter shade when grown in Scania (Skåne), the southern province. This is in no sense an hereditary change, neither is degeneration. The alteration in color is simply the result of a chan environment. According to investigations by Atterberg of Kalmar the centage of phosphoric acid in the soil has a decided influence on col grain. Soil rather than climate is in fact generally regarded as the potent factor in effecting color changes.

V.—PRACTICAL APPLICATION OF PRINCIPLES OF CEREAL BREEDING NOW RECOGNIZED AT SVALÖF.

Line-Breeding.

The work of cereal breeding at Svalöf within recent years (since 1 1902) has come to consist chiefly of *special line breeding* from the best varieties and *artificial hybridization* (46, p. 165-170; 47). By line bree is meant the taking out of individual mother plants from a mixed popu tion without special regard as to whether the said plants are botanically morphologically different or not. This practice is based on the discov that strains which may resemble each other closely in outward appeara may conceal quite distinct physiological differences. A progressive syst of selection cannot therefore be limited simply to *visibly* different strai Rather must it be extended to embrace strains which differ in physiologi characters as well. In accordance with this idea there is now taken out separate culture and for a comparison of their progeny a *large number* of plan irrespective of morphological characters. Thus has the system of exclusi Form breeding or “Form separation” of earlier days been extended to wh has come to be known as *Line Breeding*.

Still another important departure in the system of selection has been made. Where formerly starting points for new and better races were sought for from far and wide and without regard to the variety in which they were found selection is now limited to the best varieties.

The principle recognized in line breeding work at Svalöf has been widely observed in the leading breeding centres in Europe. In Denmark it is the leading principle; in Austria it is applied by Pammer and Vanha, while Fruwirth, the Austrian investigator, has discussed its merits and its advantages over the old system of Form-separation.

Line-Breeding from old varieties must continue

While artificial hybridization, as we shall see in a moment, must occupy a front place in all scientific breeding work, yet the search for superior biotypes among the best old varieties must always be pushed forward with zeal and intelligence. The possibility of locating superior types through line-breeding, together with the fact that only a comparatively small number of individuals can be tested at a time renders it practically impossible to completely exhaust the material which nature offers. The rich experience of the Scandinavians as well as that of other Europeans has led to the almost unanimous opinion that old races, especially in the case of oats and barley, should not be allowed to become extinct. The reason for this opinion is that once an old race disappears there may go with it a valuable source of new and still unexploited material. At the International Congress of Agriculture at Vienna, 1907, it was resolved "that a systematic collection of old native races be made and that these be carefully catalogued and described as a basis for further breeding." A committee consisting of such men as Fruwirth, Tschermak, Eriksson, Vanha and others was appointed to take this matter in hand and work out a basis for the preservation and further exploitation of native races.*

The popularity of the leading pedigree oat sorts in Sweden affords a striking example of the manner in which an old race can come to be displaced. Thus the *Victory oat* has largely displaced the common Probstier variety from which variety were taken practically all the best pedigree sorts of white oats of medium-early ripening type now in cultivation in Scandinavia. Fortunately the Danes retained a sort belonging to this group known as *Danish Island*, and from which a sample was secured six years ago for testing at Svalöf. The results of this test were surprising in that the old discarded mixed sort has excelled all new pedigree sorts tested with the exception of *Victory*. A number of new lines have been developed out of several hundred taken in line-breeding work from this old sort, and results to date seem to indicate that at least one of these will come to occupy first place.

In regard to the common autumn wheats of middle Sweden, Nilsson-Ehle has made a strong plea for their conservation in view of the many desirable qualities which they possess. Despite all the work which has been done with wheat, these sorts still hold first place in respect of hardiness and quality, although *Bore* and *Pudel*, two pedigree sorts to be described later, seem to combine a greater number of good qualities, such as yield and stiffness of straw, with a reasonable degree of hardiness. The above author

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*Internat. landwirtsch. Kongress. Vienna 1907.

(47, p. 11) says:—"Even if the new sorts actually are superior and deserve to be spread, it may nevertheless be insisted that by displacing the old so-called native sorts there may be a danger of losing for all time many valuable constituents which they may possess and which might become of value in breeding work. From this standpoint it is necessary that the old sorts be conserved and further worked upon." These experiences would seem to indicate the advisability of a breeding station adopting some definite plan whereby representative cultures of the best old races may be retained in their natural composite condition in order that a perennial source of new selections and material for continued crossing work may thus be provided.

Artificial hybridization

Investigation into the origin of hereditary variations in cultivated crops having led to the conclusion that these variations consist very largely of different combinations of segregating units or factors resulting from natural crossing, the breeder's whole manner of thinking must be guided by those laws upon which the performance of such products is based. He must not only seek to take advantage of such combinations as nature has already provided, but he must at the same time bring his own skill and intelligence to bear in endeavouring to effect artificially still better unions. Since the reappearance in 1900 of Mendel's epoch-making papers on heredity, artificial crossing has been elevated, not only to a process of immense scientific interest, but to one of great practical importance. Although this process had occupied a prominent place in the work of different breeders for many years previous, having been practised by Knight during the early part of the Nineteenth Century and later by such savants as Vilmorin, Bestehorn, Cymbal and many others, yet its significance was not fully appreciated until after the true nature of hereditary variations and the idea of segregation and combinations was explained by Mendel.

Experience gained in the application of this law during the past ten years seems to afford clear and convincing evidence as to why earlier attempts at hybridization at Svalöf were unproductive of results. The following are submitted as the main causes:—

1. The sorts chosen as parents were neither suitable for cultivation nor were they crossed with any idea of effecting a *combination* of characters. A good example is given in the crossing between *Old Squarehead* and *Dividend* Autumn wheats. Many crosses were also made between Spring wheat sorts whose values had not been sufficiently tested and which were later found to be of little consequence. It is now recognized that if results are to be expected, the crossed varieties must be fully known with respect to their practical value when grown under given conditions and the crosses must always be made with a definite purpose of combination.

2. Sorts were crossed which were too unlike each other, *e.g.*: the *English Squarehead* wheat was crossed on the *Swedish velvet chaff*, two sorts which are widely different in character, both as regards type of plant and winter-hardiness. In such cases the greater number of differentiating units to be dealt with make possible the creation of a great number of different combinations, thus rendering the work difficult and precarious.

3. The use of defective methods of selecting the progeny of crossings, the custom being to select on the basis of morphological characters only.

As a result of this practice, a relatively small number of the possible combinations were taken into consideration. Since heterozygous and homozygous forms are often quite similar in appearance, and since individuals of the same morphological aspect can be very different in physiological characters, and thus be of very different practical value, all promising individuals in the early generations of a crossing must be taken for separate propagation and study. The significance of this method is evident, especially when sorts which resemble each other closely in morphological characters are crossed. When the principle of Mendelism became better understood, it was quickly seen that the system of pedigree selection after artificial crossing is even more necessary than is this method in ordinary line-breeding work where only constant combinations are considered. Indeed, Mendel may be said to be the real founder of the scientific principle of pedigree selection, while Vilmorin was the first to apply it in practice.

During the early years in which breeders sought to apply the Mendelian principle, certain workers were led to believe that many crosses did not display the Mendelian proportions, a fact which served to prevent the universal acceptation of the law as such. Within more recent years, however, students of heredity seem to have more clearly interpreted the fundamental principles involved and have thus found a satisfactory explanation for many of these apparant irregularities.

The necessity of systematic crossing work

Following the discovery of the numerous distinct and constant forms which go to make up many of our old races, it was believed that artificial crossing work as a means of producing further material would seldom be required. Experience, however, seems to have taught otherwise. True, progress has been made and superior sorts have been developed by taking what nature already offered, but in a great many cases some of the most promising of these sorts in regard to certain qualities have been conspicuously weak in others. Thus selections for such specific characters as stiffness of straw, rust resistance, winter-hardiness (in autumn sown crops) early, maturing, high yield, etc., have been made from old varieties on an extensive scale, and while an advance has been made in some cases, yet the problem has not proven an easy one. It has, in fact, been found difficult to obtain in old races, strains which combine the best of all qualities. A good example is afforded in connection with an attempt to obtain a special winter hardy strain of wheat from the *Grenadier* variety by carefully removing all the weak and damaged plants from this variety after each severe winter. After the hard winter of 1901, a selection was made of plants which had survived the severe conditions of that memorable year. These plants were propagated separately as pedigree cultures where practically all proved hardier than the parent sort. The most promising of these cultures was multiplied and an Elite stock handed over to the Swedish Seed Company in the Spring of 1903 for commercial exploitation. The summer of 1903 proved a very bad one for rust, a circumstance which revealed the interesting though disappointing fact that this new winter-hardy sort which previously had proven so promising, was extremely susceptible to the above disease and was quite useless fo commercial purposes.

Another pedigree sort, taken from the *Extra Squarehead* autumn wheat proved considerably more winter hardy than the latter, but was found to b weaker in the straw. An advance had thus been made in one direction at th expense of another. Certain selections taken from *Selected* (*Renodlad*) *Squarehead* have excelled it slightly in yield, but also seem less strong in th straw. (See F. 25).

The difficulties associated with line-breeding work now seem easy o explanation. The various strains or biotypes found in old races are th result of a planless crossing in nature and as such are comparable with thos which were produced artificially at Svalöf before the combinations idea ha been developed, and with the results already indicated. In the light of th above idea, it seems clear that the prospects of success are infinitely greate where crossing work is prosecuted *systematically* and with an idea of effectin some definite combination of desirable characters. The sorts to be crosse must also be especially chosen and a careful exploitation made of all combinations which approximate the desired end. In accordance with the abov principle, artificial crossing work has come to occupy a front place in th general system of cereal breeding at Svalöf.

While some progress has been made in isolating from old varieties o autumn wheat, strains which are more winter hardy than the latter, yet a strain combining a sufficient degree of hardiness with the productivity of th best yielder has not yet been obtained from this source. Artificial crossin has therefore been resorted to and has resulted in very evident progress, th sort known as *Extra Squarehead No. II* standing as the most conspicuou monument to the efforts put forth in this direction. Thus far no sort ha been obtained which combines the maximum yielding power of the highest yielder and the maximum strength of straw of the stiffest sort with the degre of hardiness of the common Swedish sorts, although progress is graduall being made in this direction by continued cross-breeding work.

Efforts to find in old races, strains combining early maturity with hig yield, while by no means fruitless, have not fulfilled earlier expectation The high yielding though relatively early maturing *Gold Rain* oats (isolate from the old *Probstier* variety) is perhaps the best example of progress i this direction. Notwithstanding all efforts which have been made howeve to obtain still earlier sorts of equal yielding capacity by a further exploitatio of the above old variety, not a single instance of real progress is on recor True, somewhat earlier sorts have been discovered, but these have prove defective in certain other essential qualities and have thus marked no rea advance. Thus the sort *0336* (40, p. 14), though somewhat earlier than *Gol Rain*, was found to be weak in the straw and was consequently abandone Artificial crossing between early sorts is therefore being prosecuted as means of obtaining that which selection failed to give.

In the prosecution of crossing work due regard is taken of the fact tha sorts which are morphologically alike may be constitutionally different, an may when crossed, produce *gradations* which excell both parents in regard t certain practical qualities. Thus "When the specific aim is to obtain higher yielding sort by crossing, the principle has become to cross the two highest yielding sorts with each other. This principle recognizes that the specific yielding power of a sort is not to be regarded as a character in itself, but rather as the result of a combination of many different factors. When one crosses two sorts or, in other words, two combinations of characters, which give the same average yield it is quite conceivable that the numerous factors which determine yield can combine themselves in such a manner as to produce sorts which are more productive than either of the parents." (46, p. 169).

A good example of the application of this principle is found in the crossing between the two high yielding autumn wheat sorts *Extra Squarehead II* × *Tystofte Small*. In oats the crossing between *Victory* and *Nasgaard*, the two best yielding sorts in Sweden and Denmark respectively at the present time, affords another good example, while in barley the high yielders *Hannchen* and *Gold* have been crossed with the hope of obtaining among other things a still further advance in yield.

The above principle is also applied when seeking to improve upon certain other practical qualities such as resistance against disease, strength of straw, earliness of maturity, etc.

From the above discussion it will be seen that crossings made at Svalöf are of two kinds in respect of the sorts used as parents, viz.: crossings between pedigree sorts taken from the same old variety (*e.g.*, *Victory* and *Danish Nasgaard* oats, both out of the old *Probstier* variety) and between sorts of different origin.

In all crossing work, care is taken ordinarily to avoid crossing sorts which are too dissimilar in character. While it is fully recognized that progress may be made by such a method, yet the difficulty of combining the desirable characters of the parents is found to be greater in such cases. It is considered safer practice not to try to obtain too much at the one time. This principle also reduces one of the difficulties in crossing work, viz.: the tendency toward sterility in oats and low quality in wheat. When widely different oat sorts are crossed the sterility of the hybrids has always been a great hindrance to progress. Thus, in crossing *Great Mogul* with *Probstier* great sterility is met with.

Repeated crossings.

In order to take full advantage of all possible combinations which may arise between the units involved in a crossing, repeated crossings may often be made to advantage. Such repeated crossings have already been made at Svalöf. A good example is given in the cross *Extra Squarehead II* × *Grenadier*, the latter being one of the parents of the former sort.

Obtaining constancy in new combinations.

It is a common observation that constancy after crossing is obtained only gradually. The law of Mendel teaches that each single character in a certain proportion of the various combinations produced becomes constant in each generation, but since many characters may be involved it may happen that one character may become constant in a certain individual while another character in the same individual may segregate. Thus a certain wheat culture in the second generation (F_2) might possess a constant color of chaff with an inconstant color or quality of kernel. Obviously the time required to obtain full constancy in all characters depends largely upon the number of different characters concerned in the crossing. When crossing are made between closely related forms, it is not difficult to obtain a sufficien degree of constancy in selected combinations in a relatively short time.

Selection as practised with the progeny of artificial crossings correspond closely in principle with that followed in the isolation of lines (line-breeding from a common population. Practically the only difference between the tw cases is that in the application of line-breeding to artificial crossing products selection is continued until sufficient constancy is reached in the selecte combinations. The details of the method of selection practised in such case will be discussed later.

While it is undoubtedly of great importance in the majority of case that well known and thoroughly tested pedigree sorts be used as parents i crossing work, yet on account of the great length of time which is often necessary before such sorts are available, it is not advised to forego crossing wor entirely during this time. Rather is it believed that crossing should continu as a parallel work, providing known old varieties which seem to offer possibilities along this line are available. A good illustration to show that common unselected variety may sometimes be used to advantage in crossin work is found in a crossing between the wheat sorts *Pudel* and the commo *Swedish velvet chaff*.

The actual labor and time required in connection with crossing wor during the first two years is so small that it is regarded a good practice t always have on hand crossing material of at least the second generation (F_2) from promising sorts which are under trial, in order that just this much tim may be saved should the results of such trials justify the prosecution o further work with a given cross. This plan has been followed at Svalöf fo some years and in several cases has resulted in saving considerable time.

Creating of plant populations.

Still another course of procedure in crossing work, especially wit autumn wheat, has begun to be practised at Svalöf, viz., *the creating* *populations* (46, p. 169). Two known sorts are crossed and the whol progeny from all second and succeeding generations is sown together *masse.* The object of this plan is to allow the severe conditions of winte and early spring to either destroy or expose the weaknesses of as many the more delicate combinations as possible. In the latter case the breede is given an opportunity of assisting nature in her work of elimination b practising a form of mass-selection. While there is thus effected in a ver simple manner, a gradual weeding out of a great mass of unfit combination the progeny of a crossing at the same time gradually assumes the characte of an ordinary mixed population, the different combinations becomin automatically constant as time passes. The advantages of working wit constant forms will be appreciated by all breeders as will also the fact tha through the above arrangement the number of combinations which may aris through the repeated segregation of inconstant forms in each succeedin generation will have increased immensely.

The above system has been followed with the wheat crossing *0235* (ou of Selected Squarehead) and *0470* (out of English Stand-Up).*

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*See Vägledning på 1909 års försöksfält vid Svalöf, p. 8, Field Number 42.

The object of this particular crossing is to combine the hardiness of *Squarehead* with the higher yield of *Stand-Up*. The latter sort being less hardy, combinations may be expected which are incapable of withstanding the rigors of a severe winter. Obviously it would be waste of time to work with cultures which only await specially severe conditions to be entirely destroyed. The method in question allows nature, with the help of man, to gradually weed out the weaker combinations so that after a few generations only tried and constant forms remain. It is now proposed to make line selections on a large scale from the above population. Such selections from a population of known parentage are regarded as much more hopeful than where one must deal with an unknown quantity as in the case of common varieties. In the autumn wheat crossing *Grenadier* × *Cone* the severe winter of 1905 performed a selective influence among the hybrids by either entirely destroying the less hardy or by revealing their weaknesses so that a mass-selection of strong hardy individuals could be made. While the above system requires a considerable length of time before any definite results can be reached, yet it requires very little work until the time comes to make selections. Numerous crossings of this kind may therefore be carried forward with the regular work and thus provide a constant source of new material.

In discussing the present status of the place of cross-breeding in cereal improvement work Fruwirth (12) combines the conclusions of Nilsson-Ehle and Tedin of Svalöf with that of Tschermak and others thus: "That this branch shall leave rich returns can no longer be doubted".

Mass-selection.

Mass-selection, and the high state of development to which it attained at Svalöf during the early years of the existence of that Institution, has already been explained in detail (See page 18). While this system was doomed to occupy a secondary place in advanced breeding work and while there are doubtless certain dangers associated with such a system, yet there are good scientific as well as practical reasons why this method can still be of service. In the first place a mass-selected stock, containing as it may a number of distinct biotypes of varying potentialities may be able to give higher average returns over a series of years and under a variety of conditions than a pedigree sort which constitutes a single biotype, requiring as it may more exact conditions. While the advantages of pedigree sorts cannot be denied, yet on no account is it advised that such sorts be allowed to displace a mass-selected sort of recognized value until the two have been carefully compared.

Mass selected sorts must not be discarded too hastily.

Mass-selection has proven especially useful both after crossing and in ordinary line-breeding work with autumn sown sorts. In both cases it has served to assist nature in eliminating the delicate and in conserving the hardy. The mass-selected Squarehead wheat sort, *Svalöfs' Renodlad* (*Selected*) *Squarehead*, stands as a monument to the usefulness of this system.

Mass-selection as a forerunner of pedigree selection.

As a forerunner of pedigree selection from old mixed varieties the value of mass-selection is fully recognized. By reason of the inability to test more than a few dozen pedigree cultures at the same time it is important that there be included among them as few inferior ones as possible. Two or three years of mass-selection as a preparatory work, is believed to be capable of reducing very materially, the chances of selecting many such types. A good example of the validity of such a claim is afforded in the mass-selection of heads m in 1905 from an old pedigree sort originating from *Grenadier* autumn wh (50, p. 340). The sort in question was grown on an ordinary farm n Svalöf and the selection was made from the sheaf by one of the experts the Station. In making this selection care was taken to select only he which were typical and which contained fine, plump kernels. The seed fr the selected heads was sown in the large comparative trial plots in 19 where it proved promising. The severe winter of 1908-09 also showed t sort to be hardier than the mother sort, while in yield it excelled all othe On the average of the past five years (1906-1910) it stands next to *Ex Squarehead II* in yield as will be seen in the following table:

	Pounds per acre.					
	1906	1907	1908	1909	1910	Avera
Extra Squarehead II, (artificial crossing)	5,148	3,180	3,909	2,904	4,382	3,92
Selected Grenadier (mass-selection from a pedigree sort)........	5,175	2,699	3,581	3,300	4,257	3 80
Selected Squarehead (ordinary mass-selected sort)........	5,291	2,440	3,189	3,046	4,649	3,72
Bore (pedigree sort)........	4,863	2,458	3,421	2,583	4,079	3,48

The above instance illustrates two important facts, viz.: That it often possible to affect improvements by mass-selection and secondly, th even pedigree sorts, at least in the case of wheat, when grown for a period years in the country, can often be still further improved upon.

Purity of sorts maintained by mass-selection or 'rogueing.'

As a means of maintaining purity and constancy in all sorts, pedigr sorts included, mass-selection is still recommended. Where this cannot l done *rogueing,* that is removing all aberrant plants before harvesting, shou be followed. This practice is zealously followed each year by the Swedis Seed Company with all its large cultures of autumn wheat grown on its far at Svalöf.

Value of a special seed plot.

From the above discussion it follows that mass-selection by the farme in one form or another should be an annual task. By rogueing those fiel from which he intends to take his next year's seed the purity of his stoc may be maintained. By operating a *special seed plot* each year and selectin therefrom a sufficient quantity of typical heads or panicles to provide see for the following year's plot not only will the purity and uniformity of th stock be maintained with greater assurance, but in many cases furthe improvement may actually take place. The use of such a plot on ever farm on which seed growing is being prosecuted is strongly recommende by the Swedish experts.

In making such selection the operator should be content with typica plants and heads and should avoid extremes. The reasons for such precau tion have been amply demonstrated.

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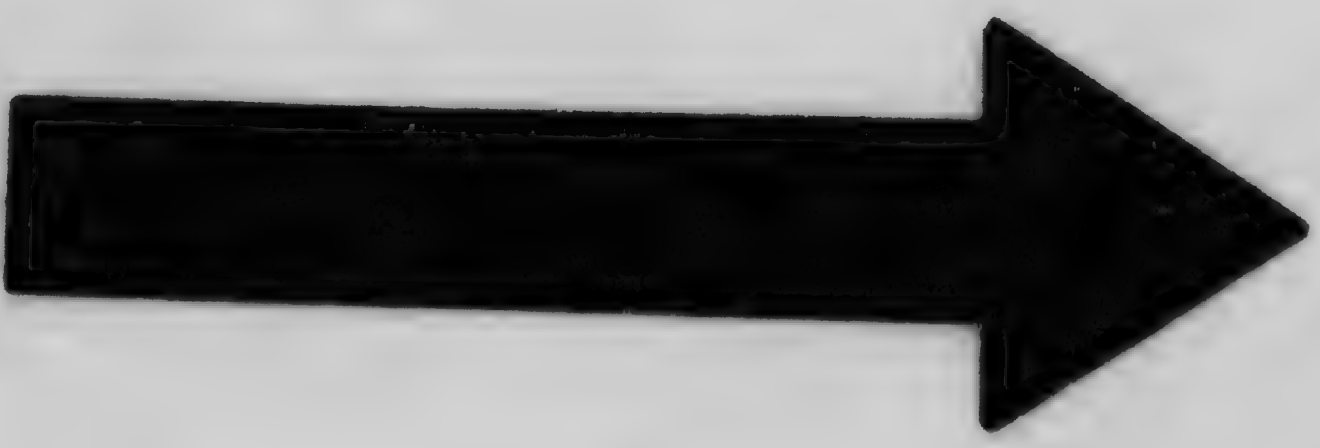
FIG. XIV.—Removing impurities by hand at harvest from large culture of Elite Stock Seed grown at Svalöf.

Photo by courtesy S. S. Ass'n.



MICROCOPY RESOLUTION TEST CHART

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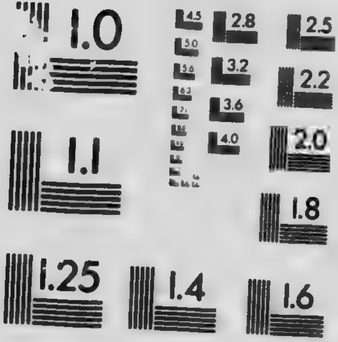

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From the above review of the principles recognized in connection with plant improvement work at Svalöf, it will be seen that all possible ways of reaching the desired end are employed. *Line-breeding from old races, artificial cross-fertilization and mass-selection* each occupy a place, and may indeed be regarded as the tripod of progression in the scientific breeding of plants.

Practical Importance of Sort Purity.

The experience of the men both at the Scientific Station and at the Seed Company at Svalöf has amply demonstrated the great practical importance of sort purity. Many farmers, however, do not regard purity as a matter of great concern, but continue to use impure seed from year to year. A brief consideration of this question should be appropriate here.

Definition of a 'sort.'

Tedlin (67, p. 142) defines a sort as *"a group of plants all possessed of the same botanical and constant characters which distinguish it from all other sorts or races. If a group cannot fulfill these conditions it is not a sort but a mixture of two or more such."* Since the main object of breeding work is to produce new and better sorts and since a true sort represents a definite and characteristic entity, different in certain essential regards from all other sorts, it is of great importance that its purity and therefore its identity be maintained. Especially is this the case in brewing barley. The ability to recognize a sort is important from a purely commercial standpoint, as it prevents misrepresentation, fraud and all the serious consequences which may follow. Concrete instances of how this power to identify a sort may operate, are on record at Svalöf. Mixed races may not only be troublesome to the breeder who must keep a close check on all leading sorts under cultivation, but they may become a source of much annoyance and trouble to those who buy seed. The farmer who grows his own seed may not regard the question of purity as of great importance. Certainly it is not impossible for an impure sort to give good returns for a year or two or even longer. When one considers, however, the rapidity with which the number of distinct biotypes or strains may become augmented by an occasional natural crossing between them the danger of such practice will become apparent. Since such forms are often found to display differences in regard to date of ripening, size of kernel, per cent of hull, strength of straw, etc., although perhaps not strikingly apparent when growing together, it is not difficult to anticipate the possible losses that may accrue. Sort purity to the farmer, is therefore quite as important as to the commercial dealer and to the breeder, in fact it is upon the losses which the actual grower may suffer that the chief significance of a pure condition, at least in most crops, rests. In practice it has not been found possible to maintain absolute purity. A certain margin of tolerance must therefore be allowed.

While the evidence seems strongly in favour of pure sorts, yet it is shown that mixed or composite varieties may have their advantages *under certain circumstances*. Thus a variety may contain strains which differ from each other chiefly in their attitudes towards different conditions of soil and season.

They may be almost identical in appearance, may ripen simultaneously, may possess the same stiffness of straw and the same resistance against disease yet one may thrive best on soils which are relatively light, warm and dry while another may give better results on a heavier, colder and moister soil. Were a variety of such composition sown on a field in which the soil is exceedingly variable, it is conceivable that a better average may be obtained than from an absolutely pure sort which demands more exact conditions. The difficulty of knowing the real nature of the strains which go to make up a mixed variety is such, however, as to render it an unsafe practice to depend upon the possible virtues of a composite race.

VI.—METHODS OF WORK IN CEREAL BREEDING AT SVALÖF

The inability to determine the industrial worth either of an individual or of a strain on the basis of morphological characters has led to the adoption and gradual perfection of methods based upon *direct judgment.*

Thus all plants selected as possible mothers from composite varieties, or produced by artificial crossing must, if sufficiently promising, pass through a long and arduous period of investigation, first in *pedigree cultures*, then in *preliminary trial plots* and finally in the *large comparative trial plots* (See Fig. 15). In all cases *yield* constitutes a leading basis of valuation in view of the fact that this is regarded as a highly complex character, being an expression of many different factors.

Since it is seldom found practicable to work with more than from one hundred to two hundred cultures from a given variety or crossing at the same time and since it is of the utmost importance that the initial choice of mother plants be made as advantageously as possible, two or three years of mass-selection as a preliminary work is advised.

Size and arrangement of plots.

The necessity of handling a large number of plots of various sizes and which represent different stages in the system of improvement, requires that the field work be arranged as systematically and economically as possible. The plots are therefore laid out in ranges with great care and precision. Each plot in the experimental grounds is separated from its neighbor by a narrow space which in all cases is sown with some other kind of culture plant such as spring rye or flax (See Fig. 16). In this way there is avoided any extra stimulation of outer rows which otherwise would render the plots uneven and abnormal. This growth of plants between plots is also believed to afford a measure of protection not only against cross-fertilization, which even in normally self-fertilizing cereals has always to be reckoned with, but also against the accidental mixing of the product of different plots.

Pedigree cultures.

The ranges occupied by the small pedigree plots are usually narrow, 1.50 metres (39″) being the common width. The seed is planted in rows by hand with the aid of the "marker," one seed being dropped in a place (See Fig. 16). The distance between each row is 15 centimetres (about 6 inches), while the plants within the row are 5 centimetres (about 2 inches) apart. The object in planting with such exactness is to give each plant as nearly

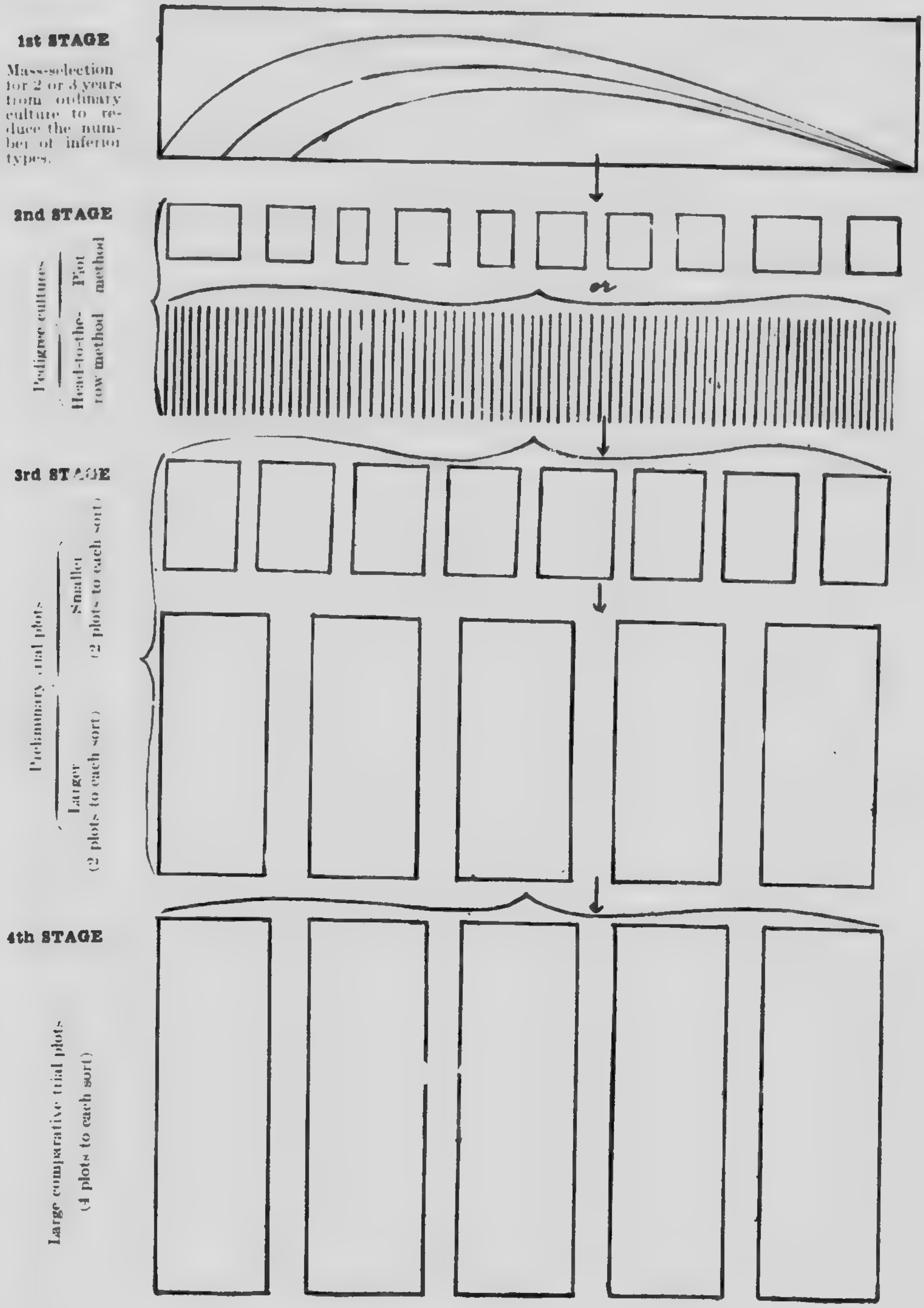

1st STAGE
Mass-selection for 2 or 3 years from ordinary culture to reduce the number of inferior types.
2nd STAGE
Pedigree cultures
Plot method
Head-to-the-row method
or
3rd STAGE
Preliminary trial plots
Smaller (2 plots to each sort)
Larger (2 plots to each sort)
4th STAGE
Large comparative trial plots (4 plots to each sort)

FIG. XV.—Scheme showing general course of procedure recommended at Svalöf in ordinary line-breeding work. This plan may be varied in every conceivable way. (Author del.)

equal conditions as possible and at the same time to allow single plants to be taken up by the roots for furthur study. After due examination in the field, those cultures, especially in the case of wheat and oats, which reveal outstanding defects such as weakness of straw or susceptibility to disease are at once permanently rejected. The remaining cultures are carefully harvested by hand all plants being pulled up by the roots, tied into bundles, taken to the drying room and finally to the laboratory to undergo further examination. In the case of barley the treatment is somewhat different as this plant is so susceptible to external conditions that it is seldom considered safe when dealing with such small plots, to reject any considerable number of them the first year. The first serious attempt to eliminate barley strains is therefore made the second year when the plots are larger.

Photo by L. H. N.

FIG. XVI.—A large comparative trial plot of Grenadier II Autumn Wheat separated from its neighbor by a narrow strip of Spring rye seen on left of illustration.

Head-to-the-row method.

A further measure which is coming to be used at Svalöf as a form of pedigree taking is what is known as the *head-to-the-row* method. By this method a large number of heads, representing as many different plants, are plucked from the crop when mature. From each of these heads a definite number of kernels (from 30 to 60 in the case of wheat) is taken to plant a single row. The rows are consequently all of the same length. Careful field notes are taken throughout the summer and in due time the absolute weight of grain and weight per 1,000 kernels of each row is also determined. On this basis a choice of rows and a reduction to perhaps half the number is made. The product of each of the selected rows is used to plant as many plots the following year. Up to the present these plots have been of different sizes, but now they are of equal dimensions in order that continued yielding tests may be taken as an aid to field notes in the elimination of presumably inferior strains.

In ordinary line-breeding work the seed from the 100-200 selected plants is planted in plots of *varying* sizes, depending upon the number of kernels available from each plant. The average size of plot in the case of autumn wheat is about .75 m. × 1.5 m. (19½″ × 39″).

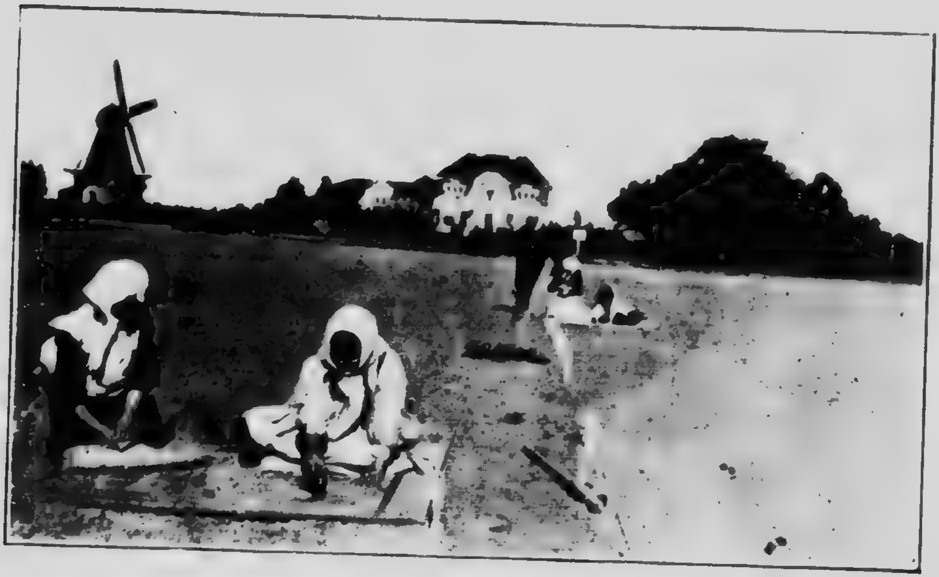


Photo by L. H. N.

FIG. XVII.—Sowing pedigree plots of wheat and Rye at Svalöf. Range on right Rye, that on left Wheat. By alternating the ranges in this way a measure of protection against crossing is afforded.

By the head-to-the-row method it is possible to handle a much greater number of different cultures than where ordinary pedigree plots are used. In the former case however, it is more difficult to judge certain characters such as strength of straw, than it is in the latter. The method to be used in a given case must therefore depend upon circumstances.

Such pedigree plots or *rows*, as seem worthy of further consideration are carried forward into larger plots for further study and comparison on the basis of yield and other qualities. These plots are called *preliminary trial*

Prelim
trial pl

plots (See Fig. 17) and may be said to be intermediate between the small pedigree plots and the large comparative yielding trial plots. Each strain occupies two of these plots and the average grain production of the two is accepted as the expression of yield. The main object of these plots is to eliminate all cultures except a few—perhaps three or more—of the very best. These are to be carried forward to the large comparative trial plots which are yet to be described.

Of these preliminary plots there are two series which are distinguished on the basis of size and manner of sowing. The smaller is 4.50 square metres in size and is *planted by hand* with the marker which is so regulated that exactly 600 seeds, one seed in a place, may be planted on each plot. In oats and wheat this area is arranged in an oblong plot 0.75 m. × 6 m., while in barley the plots are wider and shorter, viz., 3 m. × 1.50 m., although the total area in each case is exactly the same. The object of a special arrangement for barley plots is to reduce the number of border plants as much as possible, these having to be discarded on account of abnormal development.

Photo by L. H. N.

Fig. XVIII.—Preliminary trial plots of Autumn Wheat in foreground, smaller pedigree plots in background, (Jan. 2, 1911.)

The total product of the oat and wheat plots is cut with the scythe, stooked, threshed and the yield taken. In barley, on the other hand, only the sound normal plants from the inner part of the plot are taken into consideration. These are taken up by the roots with great care, tied into bundles, taken to the drying room and ultimatly to the laboratory for further study. This study is conducted along the following lines:—

1. Measurement taken of longest stem of each plant (not always).

2. Roots clipped off each plant and the whole selected product of each plot weighed.

3. Average weight per plant estimated.

4. All plants from a given plot threshed by hand and the threshed product weighed.

5. The weight of grain and straw *per plant* estimated separately on above basis.

6. Percentage production of grain from whole product estimated.

7. Weight of 1,000 representative kernels taken.

8. Hectolitre (2.85 bushels) weight of average sample taken.

9. Examination of grain for plumpness, character of scale, etc.

On the basis of the above analysis together with notes taken in the field regarding such matters as strength of straw, date of maturity, etc., a very considerable reduction in the number of these plots is made.

Photo by L. H. N.

Fig. XIX.—Dr. Nilsson-Ehle, taking notes on preliminary Autumn Wheat plots, July 30.

The larger sized plots in the series of preliminary trials usually occupy an area of 12.50 square metres, being 1 metre (39.37″) wide by 12.50 metres (40.3′) long. In some cases a greater length is allowed. These plots are *sown with a small two-drill machine*, the drills being 15 c.m. (5.85″) apart, thus allowing six drills to each plot. Into these larger plots are carried practically all sorts which have survived the tests of the smaller series, in order that a more accurate comparison of yield may be made. Here again each sort usually occupies two plots which are located some distance from each other, with a view to equalizing as far as possible, the effects of soil variations, etc. The value of these preliminary yielding tests has been repeatedly proven, showing as they do how easily one may be deceived by appearances. A good example is given in the crossing between *Cone* and *Grenadier* wheat. Here two lines in the fifth generation, judged from appearances, seemed equally promising, but the yielding tests, even on these small plots, revealed a decided difference and on this evidence the choice was made. The best yielding line came into the large comparative trial plots in 1909, since when it has shown the same good yielding power which distinguished it in the smaller plot.

Large comparative trial plots.

The large comparative plots determine the fate of a given sort, in so far as such can be determined at the station, as here it must enter into competition with the very best old and new sorts.

All sorts which have been produced by the Association and which are now on the market must be represented in these trials in order that later productions may be compared with them. Only in this way is it possible to know whether a new sort is better than the old and thus deserves to come into general cultivation.

When a sort of good repute is first imported from another country it is placed either directly in these trials or tested for a year or two in the preliminary trials. If it proves promising and is not already a pedigree sort, a number of plants may, under certain circumstances, be taken for pedigree culture. If, on the other hand, it is known to be a pedigree sort no further selection is given it, its future depending entirely upon its performance in comparison with other sorts. Each of these large trial plots is 2 metres wide (about 6½ feet) by 25 metres (82') long, therefore occupying about .012 acres. Heretofore each sort occupied three such plots but in 1910, owing to the great importance of equalizing soil variations, arrangements were made to increase the number to four, although the size of each plot was reduced so that practically the same total area will still be occupied. While even a greater number of plots should properly be devoted to each sort, yet owing to the fact that a large number of sorts must always be under trial, it is not found practicable to handle more than four. In arranging the different plots care is taken that no two plots of the same sort adjoin each other. By this arrangement variations in the quality and character of the soil may be overcome materially, and thus a fairer expression of the yielding power of each sort obtained.

These plots are sown with a small one-horse machine of 7 drills, each plot having 14 drills (See Fig. 20). This machine is extremely simple and can be thoroughly cleaned of all seed within the shortest possible time. A new machine has recently been devised by Mr. W. Kinberg, field foreman at Svalöf, as a result of the past 20 years' experience which marks certain improvements over that formerly used. This machine is based on the *Sachs* System, but includes a number of changes which render it more suitable for sowing small experimental plots.

By the above system of comparative trial plots not only are the results considered to be infinitely more reliable than a one-plot system, but the time required to ascertain the standing of a given sort is considerably shortened.

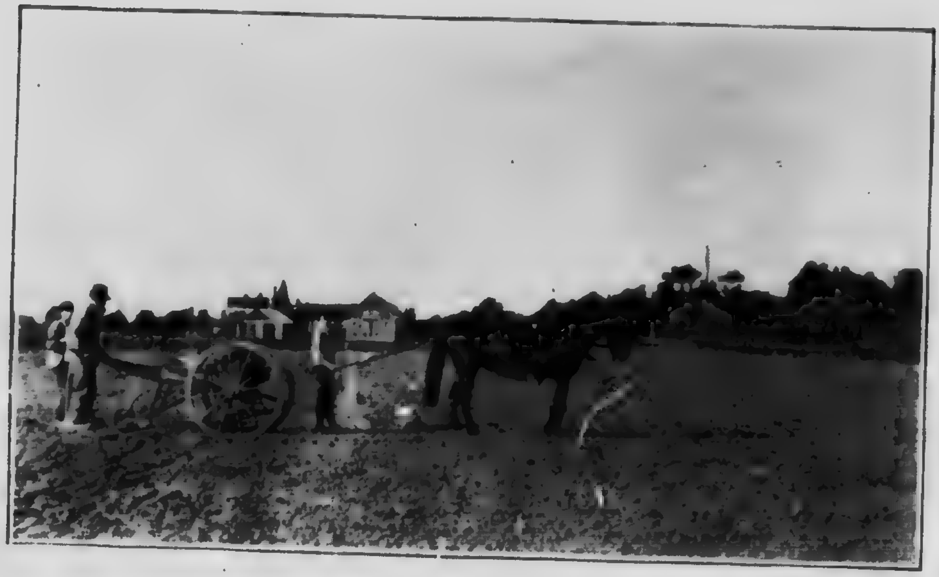


Photo by L. H. N.

Fig. XX.—Sowing large comparative trial plots of wheat on Experimental Grounds, Svalöf.

In Denmark the system of determining the yield of sorts under trial has attained its highest development. Each sort occupies not less than six plots, while not infrequently as many as twelve are used. Here, however, only a relatively small number of different sorts are tested at the one time. Between every two plots a *standard sort* is used for comparison. This system is admittedly more or less complicated, but is considered more reliable where a final decision must be made between sorts of nearly equal value.

While yield must be one of the leading considerations in sort testing, other characters such as quality, date of maturity, strength of straw and resistance to disease may be of equal if not indeed, even greater importance. The method of recording yields as well as certain other characters is indicated in the following table in which the performance of the first three out of twenty-seven barley sorts is given (76, p. 246):—

TWO-ROWED BARLEY.

Field No. (1909)	Sort	Yield of grain per plot of 50 sq. metres, 1909			Crop in kilograms per hectare (2·47 acres)			Weight per 1,000 kernels (grams)	Weight per Hectolitre (2·85 Bus.) 1909, (Kilograms)
		Plot I	Plot II	Plot III	Grain		Straw		
					1909	Average 1907-09			
1	Old Native Barley of Skåne..	17·8	14·2	16·8	3,250	....	4,270	44·4	66·3
2	0105 Svalöf's Princess	17·0	15·0	16·5	3,230	3,390	4,480	37·1	63·8
3	0110 Svalöf's Hannchen...	15·8	11·7	16·6	2,940	3,290	3,730	41·2	66·4

The importance of allotting each sort three or more plots is clearly shown in this table, as is also the necessity of giving the actual weight of grain per acre instead of the number of bushels when making a comparison of sorts of different weights.

Importance of a correct interpretation of results.

An essential feature in breeding work is the correct interpretation of results obtained from comparative trials. Where many sorts must be under test for a series of years and where new sorts are gradually being brought in and inferior sorts dropped, a reliable basis of comparison is imperative. Thus the average yield of sorts under trial from 1890 to 1906 cannot fairly be compared with the average of others which came in, say, three years later. The manner in which this difficulty is sought to be overcome at Svalöf is shown in the following table of autumn wheat [illegible] 231).

YIELD OF GRAIN FROM SOME OF THE AUTUMN WHEAT SORTS TESTED AT SVALÖF, 1890-1906.

Kilograms (2·1·5 lbs.) per hectare (2·47 acres)

SORT	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900	1901	1902	1904	1905	1906	Average yield up to and including 1905.	Average yield of Swedish velvet chaff wheat during the corresponding years.	Average yield in comparison with Swedish velvet chaff (which latter 100) up to and including 1905.
0307, Rice....							4167	4120	3320	3390	4440	2980	4240	3567			3778	2941	128·5
0501, Grenadier...	....	....	..	.	....	4710	4947	3933	3407	2570	4340	**	[illegible]	[illegible]	3933	5847	4036	3129	128·3
Shirriff....	4262	*	2733	2860	2633	4247	4300										3506	2743	127·8
0319, Cone........											3970	2807	3580	3533	4573	5853	3693	2959	124·8
Swedish Velvet Chaff.....	3157	4495	2545	2648	1367	3530	3240	2947	3267	2700	3513	1987	2773	3433	3087	4227	2957	2957	100·0

*Thinned severely during winter, no figures taken

**Killed out during winter

An examination of the preceding table will show that the common wheat of the country, viz., *Swedish Velvet Chaff*, is taken as the b[illegible] comparison.

Method of handling artificial crossing products.

The method of handling the products of artificial crossing is in principle, much the same as that employed [illegible] ordinary line breeding from old varieties, as already explained. In ordinary line-breeding the great majority of mother plants chosen are already constant and breed true. In the case of artificial crossing-products a certain proportion of each generation is at first inconstant and will divide further into constant and inconstant forms. In this case the problem is to locate those individuals which seem to show the best combination of desirable characters. This is accomplished substantially as follows:

All plants from each of the second generation plots are kept and the seed from each sown in separate cultures. Field notes are taken on the plants produced (third generation) during the growing season and at harvest a number of the best plots are chosen for further investigation. All plants from each of these selected plots are taken up by the roots, bound into a bundle, labelled and taken to the laboratory for still further examination (See Fig. 21). The line of study here naturally varies somewhat, depending upon the specific qualities sought for in a given crossing. This study together with the field notes taken earlier in the season, permits a further reduction to be made in the number of cultures, to a few of the most promising. Seed from a large number of the best developed plants within each of these selected cultures is then taken, each lot being given a number and in due time used to plant other pedigree plots (fourth generation).

Photo by L. H. N.

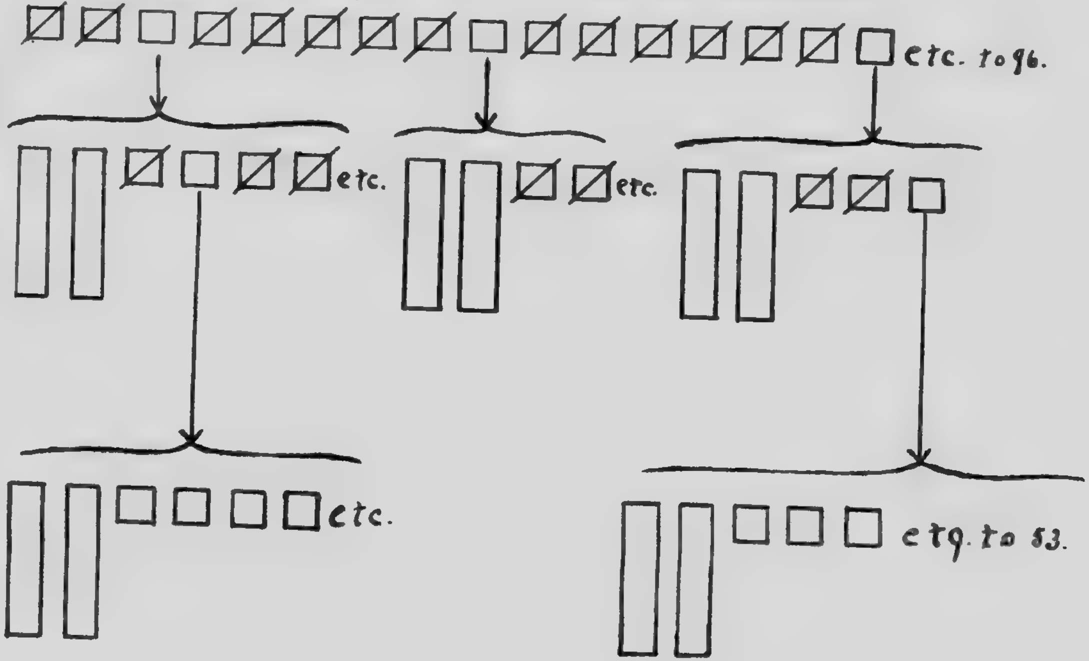
FIG. XXI.—Harvesting pedigree plots,—4th generation from the oat cross *Gold Rain* × *Dale*.

In view of the inability accurately to determine values by mere outward appearance, together with the fact that *yield*, representing as it does the product of many factors, may often be accepted as a fair index of the real worth of a sort, Nilsson-Ehle has introduced a special system, in connection with work with wheat and oats, by which yielding tests are resorted to after the third generation as an aid in determining the value of selected cultures. Thus a bulk sample of seed is taken from each of the cultures finally selected in the third generation and sown on a regular preliminary test plot. Such a plot is therefore the common representative of a whole group of fourth generation cultures whose yielding power it is supposed to express. By this arrangement it is possible to discriminate between whole groups of cultures. After choosing the most promising groups a number of the best appearing plots within each of these groups is again chosen to provide plants for new pedigrees as well as seed for further yielding tests. This process is continued until the best possible results in the desired direction are obtained.

In order to make this system more clear the following scheme, devised by Nilsson-Ehle to illustrate the actual course taken in connection with the *Pudel* × *Velvet Chaff* wheat crossing, is submitted (50, p. 343):—

Pudel × Velvet Chaff

NOTE: The plots marked ☒ indicate that these have been excluded.



Third Generation, 1908.

Thirty of these plots were chosen for further study while the remainder were thrown out. Seed from the most promising 10 out of the 30 plots was taken to plant *yielding* plots, while 165 plants were taken from the same 30 plots for further pedigrees in the

Fourth Generation, 1909.

Before harvest in 1909 nine of the most promising pedigree plots from among the 165 were chosen for further testing in small yielding plots, while from 17 of the 165 plots, a total of 53 plants was taken for further pedigree study.

Fifth Generation, 1910.

In the fifth generation there were, therefore, nine preliminary yielding trials and 53 pedigree plots from the above cross, under study.

Before harvest in 1910 seed from small multiplication plots of each of 6 of the most promising pedigrees of 1909 was sown in as many large *comparative trials.* These will probably be reduced to 2 or 3 in 1911 on the basis of yield.

Experience has shown that forms which are sufficiently constant as regards the special characters sought for can usually be isolated and admitted into the large comparative yielding trials within five generations from the cross.

Photo by L. H. N.

FIG. XXII.—View of Experimental Grounds for spring grains in 1910. Old home of Birger Welinder in distance.

Local trials and Branch Stations.

In order that an accurate idea of the value of a sort may be obtained, *local trials* and *branch stations* are absolutely necessary. The soil and climatic conditions at Svalöf have not been found either the most satisfactory or the most representative for many sorts. In barley particularly, an unusually long time is required before an accurate estimate of the value of a given sort even for the Province of *Skåne* can be ascertained. While efforts to overcome this difficulty have been made by laying a series of trial plots at a more representative point in middle Sweden (near Bålsta) yet this is not considered nearly sufficient. "*A necessary condition,*" says Tedin, (75 p. 215) "*in order that the work shall lead to results within reasonable time is that we lay each year in different districts many parallel trials to those at Svalöf, as a check on the results obtained at the latter place. No matter how long a sort is tested here, one can never draw a safe conclusion as to its suitability, for example, for the barley districts of the Province of Östergtöland.*"

Experiments in different districts and on different soils are also necessary as a means of indicating in what direction improvement should go. The breeder must seek, as far as possible, to know the character or characters which determine the suitability of a sort for given conditions. As has already been pointed out the behaviour of many sorts at Ultuna and Luleå is often quite the reverse of that at Svalöf. Oat sorts at Svalöf, for example, which show but relatively little difference in dates of ripening are found in the North to differ very decidedly in this respect. Wheat sorts which are weak strawed at Svalöf may be relatively strong at Ultuna. Certain sorts are found to be very susceptible to rust and other diseases at Svalöf while at Ultuna and elsewhere they are relatively resistant. The reverse may likewise be the case. In developing a rust resistant sort for the latter place, selections made at Svalöf might be quite susceptible to this disease, a fact which is exceedingly confusing.

It has been found very difficult accurately to estimate yields of autumn wheat sorts on account of the varying conditions with which this crop has to contend. Thus the different degrees of hardiness and the varying attitudes of the different sorts toward disease makes it absolutely necessary that tests extend over a long term of years in order that all contingencies may be met. A good example of the confusing effects of disease is afforded in the frequent occurence at Svalöf of Leptosphæra, a disease which manifests itself in lodging of the straw. This disease seems particularly insidious in the case of the common Swedish wheat and certain other varieties such as *Selected (Renodlad) Squarehead* and *Tystofte Stand.* During the bad year of 1907-08 the two latter sorts were among the poorest, while in good years they are rated among the best. In working with pure lines the need for extensive local trials seems even more urgent than in the case of mixed varieties. As previously pointed out, mixed varieties may contain strains capable of thriving under a variety of conditions. Pure lines on the other hand are likely to be adapted to more specific conditions and thus are less likely to thrive to advantage over so wide an area.

Local tests by the Government.

Local trials on a comparatively large scale are conducted by the Central Institution for Agricultural experiments (Central anstalten för försöksvasendhet på jordbruksområdet) Stockholm, in co-operation with the various agricultural societies and the Swedish Seed Association at Svalöf. All trials in a given district are supervised by the representative of that district who reports the results both to the government and to the Association.

Plan of local sort trials.

The general plan recommended for the conducting of local tests is as follows (38, p. 37):—

1. A location must be chosen in which the soil is as even as possible in quality and which is sufficiently well drained.

2. The plots must not be smaller than 50 square metres (1/82 acres) and each sort should be allowed *at least two plots* which should not adjoin each other.

3. The plots should be laid *across*, not lengthwise, of the "land" and should be oblong in shape.

4. It is better to test two or three sorts carefully in the above manner than to attempt to test many on single plots.

5. Careful notes should be taken re manner of growth, strength of straw, rust, etc., during the growing season.

6. Each plot for each sort should be threshed and weighed separately.

7. Such trials should be continued for at least two or three years as one year's experiments cannot give any reliable indication of the value of a sort.

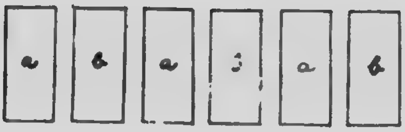
Local Breeding.

While the Branch Stations of the Swedish Association appear to be doing excellent work and while local tests conducted by interested farmers are of value as an indication of the probable value of the various sorts, yet more work in local breeding is regarded as necessary. This need has become more and more apparent with the increasing importance of methods based on direct judgment. Since the selection and elimination of cultures must be governed by actual performance, including yielding tests, and since the behaviour of a sort in a green district may be the reverse of that in another it is clear that the development of superior sorts for given localities can reach its highest point only when executed in the locality for which they are intended. This principle is coming to be observed by the Institution at Svalöf. Thus line-breeding work with the common autumn wheats of Central Sweden is now being conducted by Mr. Elofson, Superintendent of the Branch Station at Ultuna, as this work gave no results of value when prosecuted at Svalöf. The crossing *Pudel* × *Swedish Velvet Chaff* is also being investigated in a very thorough manner at Ultuna while at Luleå, Dr. Ulander, Superintendent of that station, is working with crosses between north Scandinavian early oats and later high yielding varieties, etc.

Efforts to produce on the stiff clay soils at Ultuna, a barley sort suitable for the lighter soils of the province of Dalarne have not met with great success. A permanent breeding Station at a representative point in this province is regarded as imperative. More stations in the good agricultural provinces, Östergötland (especially for barley) and Vestergötland (for wheat, oats and rye), are also believed to be an essential to further progress in these districts.

Special sort trials.

When a sort has passed the tests at Svalöf of Ultana and has likewise shown a promising record in other sort trials made by interested farmers throughout the country it is subjected to further trials bnown as *Special* sort trials in those parts of the country for which it is specially intended before being placed on the market. Adjoining this special test plot there is placed a plot of the sort which heretofore has been regarded as the most satisfactory in the district. These plots should be at least 50 square metres (1/82 acres) in size and should be in at least three series according to the following plan (43, p. 105):—



Soil as uniform as possible should be chosen so as to give each plot an equal opportunity. The seed used, both of the sort under trial and of the competing local sort, should be grown in the district in order that the quality of both may be as nearly equal as possible.

Multiplication of sorts intended for distribution.

When a sort has been under trial for a sufficient length of time to give a fair indication of its industrial value and when results to date seem to indicate that it is likely to be worthy of distribution, *a new pedigree is taken* for multiplication in order that a few bushels of seed of unquestioned purity may be available for further multiplication should the final trials warrant such. This multiplication of promising stocks in advance often saves two or three years time.

The system of sowing on the multiplication plot makes it possible to examine single plants. In the case of barley each plant is pulled up by the roots and taken to the laboratory where a single kernel is taken from each and examined with a lens. If any mixtures have accidently come in, the whole lot is rejected and a new multiplication made. This examination can be made quite rapidly, 600 plants per hour being quite within the reach of one accustomed to the work.

Measures taken to maintain the purity and identity of seed stocks.

In the absence of any organization among the farmers of Sweden, such as that provided by the Canadian Seed Growers' Association in Canada, by which special efforts are made by the farmers themselves to maintain the purity of seed, the purest stocks are often found, sooner or later, to become mixed and deficient in uniformity. In order to perpetuate pure stocks the Swedish Association keeps in reserve a small quantity of the original seed from which it makes new multiplications (renewals) from time to time as circumstances demand. These renewals are handed over to the *General Swedish Seed Company*, which has the exclusive right to receive such stocks and which multi[illegible] and handles them in a manner which has been described by the writer in [illegible]ent article.*

Book Keeping

The system of book-keeping at Svalöf is extremely simple. A single book for each kind of crop accommodates both field and laboratory notes for a given year. Each separate culture under consideration is allotted a separate page which bears the field number for the current and previous years, the stock-book number (the number under which it is registered) if it has been registered, and in due time the field number for the following year. Each of these numbers occupies a definite place on each page so that their identity is always recognized. In this simple manner it is easy to trace the ancestry of a given sort or line from generation to generation. The information regarding a certain culture, as recorded, is indicated in the following page taken from the autumn wheat book for 1910. The culture in question was a pedigree, third generation hybrid, from a crossing between the autumn wheat sorts *Grenadier* II (0501) and *Sun* (0415).

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* **"The Distribution of Improved Seed Stocks in Europe," Page 1[illegible] Seventh Annual Report of the Canadian Seed Growers' Association, Ottawa.**

0501 × 0415,—3rd Generation

1910

$\underline{226}$ *

1909

1.39 **

31

Sown.................. 29/9
Head appeared.......... 21/6
Ripe.................. 10/8

19/7 Yellow Rust 3-4
25/7 Average height
28/7 (!) Very large head
30/7 Yellow rust 3½
17/8 Straw strength 2
10/9 Not more rust than parents, kernels plainly translucent, more like 0415 in form but quality as 0501; plump but somewhat open crease.

$\underline{\underline{39}}$ *** Should be continued.

Grading Rust and Smut.

Much rust or smut is usually indicated by the figure *5*, while the absence of these diseases is indicated by 0. Intermediate degrees are indicated by corresponding numbers.

Grading strength of Straw.

The strength of straw is graded according to the following scheme, *1* indicating stiff upright straw and *6* extremely weak straw. In rye finer gradations than these are used.

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*=The field number for 1910. The sign (—) indicates that this was a pedigree culture during the year in question.

**=The field number in 1909.

***=The field number for 1911. The sign (=) indicates that this seed is to sow a comparative trial plot in 1911.

(!) Sign used to indicate a high degree of excellence.

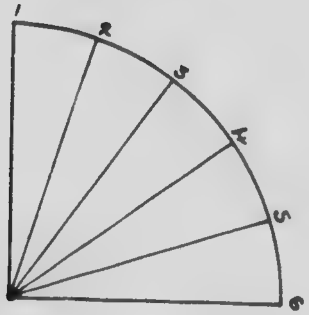

Fig. XXIII—Method of Grading Strength of Straw.

Laboratory work.

As will be seen from the above the main notes are taken in the field. The laboratory work consists chiefly in interpreting field trials by comparing yields and examining the product for quality. This work, together with the prosecution of scientific investigations intended to further elucidate problems in breeding, and the preparing of reports and other publications, requires the entire winter.

The analysis for quality of grain includes in the main the following points:—

1. Weight per 1,000 kernels.
2. Weight per hectolitre (2.85 bushels).
3. Percent hull or scale.

Photo by L. H. N.

Fig. XXIV.—Prof. Nilsson selecting Oat plants for photographing.

VII. SUMMARY OF WORK DONE WITH DIFFERENT CROPS, AND RESULTS OBTAINED.

1. The Breeding of Autumn Wheat in Sweden*

Thirty years ago the area devoted to the growing of autumn wheat in the southern parts of Sweden was much smaller than that of the present day. The so-called "land" sorts (common sorts of the country) which were then generally grown, were relatively unproductive, weak strawed and more or less susceptible to rust, their only virtues being their *quality* and *hardiness* or ability to withstand those conditions of temperature which render other sorts unsuitable.

In the early eighties importations of foreign varieties were made and tested by farmers in the southern parts of the country. Among these the *English Squarehead*, while much less hardy, was found in good years (mild winters and favorable springs) to greatly surpass the Swedish sorts in yield, stiffness of straw and resistance against rust, and thus quickly became widely distributed. This variety, however, was not hardy enough even for the most southern parts of the country and consequently not at all suitable for the north. By reason of its lack of hardiness, the average yield of this sort, after a long series of years, was found to be scarcely superior to that of the common Swedish varieties.

When the Institution at Svalöf was founded its autumn wheat work was directed towards the production of a sort of the Squarehead's good qualities combined with the superior hardiness of the common sorts of the country. This object it was thought, might be reached in either of two ways and all work was therefore turned in these directions thus:—

(a) To obtain a hardier sort from among the Squarehead varieties or

(b) To obtain from the hardy Swedish material a sort with the other good qualities of Squarehead.

Many different foreign sorts were tested in comparative trials but all were excluded except the genuine Squarehead types. Of these, a sort known as *Shirriff's Squarehead* proved the best. This sort had been introduced into Sweden about 1883 and by the continual thinning out of all weak plants by severe winters had become considerably hardier as a variety, but at the same time it had to a large extent lost its original character. Another Squarehead variety introduced in 1885 had likewise become hardier, but in this case the original Squarehead type was maintained since care had been exercised by the growers to keep only the true Squarehead type. This selection received the name *Renodlad* (*Selected*) *Squarehead.* (See Fig. 4). These two sorts formed the principal basis of breeding work with foreign sorts.

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* The data submitted herewith on work with wheat, as well as that presented later on work with oats, have been obtained from publications by Nilsson-Ehle, 1901-1910, which include annual reports on the work with these crops together with special descriptions and accounts of new sorts distributed from 1905-1910. Of special interest and value are the excellent summaries of results obtained from comparative trials made with different sorts of wheat and oats up to and including 1906, which are published in *Sveriges Utsädesförenings Tidskrift*, 1906. p. 189-308 and p. 45-81 respectively.

After the particularly severe winter of 1891 a further thinning of the above sorts was made and from the surviving plants such well known pedigree sorts as *Grenadier* and *Extra Squarehead* originated. In this way it was soon found comparatively easy to obtain hardier forms but unfortunately such forms proved, in the majority of cases, to be inferior in other essential particulars, such as yielding capacity, strength of straw and resistance against rust (See Fig. 25). The *Grenadier* however seemed an exception in that it maintained, to a large extent, the very good yielding power of the old imported *Squarehead*, while the hardiness was increased to some extent although not sufficiently even for Skåne. These three sorts became widely distributed, especially in the southern parts of the country, and were without doubt superior to the old commonly cultivated varieties.

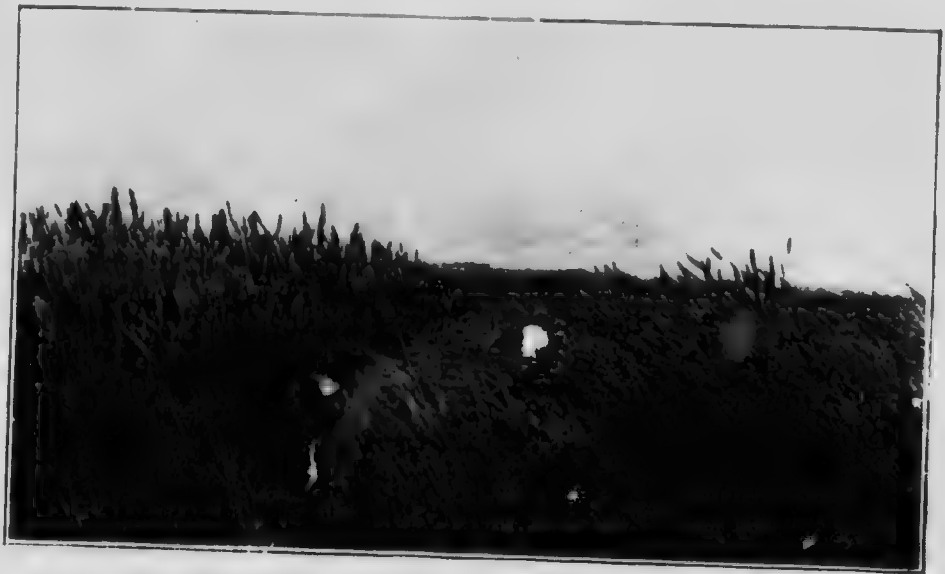

Photo by L. H. N.

FIG. XXV.—Plot of selected Squarehead wheat on left; plot on right a pedigree or pure line out of former. The pure-line in this case excels the mother sort slightly in yield but seems less strong in the straw.

A great number of strains have been taken out of the old Swedish sorts but the results have not been satisfactory in that no strain has been found which combines hardiness and good quality with high yield and stiff straw in sufficient degree. One of the best of these sorts, *Svalöf's Brown "Land" Wheat,* came on the market but as subsequent experience showed that it marked no advance over the old variety, it was finally withdrawn.

Two forms, registered under the numbers *0701* and *0516* and taken from the so-called *"Land" Wheat of Skåne,* affords an interesting illustration of how different in character, forms from an old sort may be. In a trial plot of No. *0516* there was found in 1896 an aberrant type which, on propagation, received the name *Kotte* (Cone), a sort to which reference has already been made. (See page 74). The following scheme indicates the character of these forms and gives the pedigree of *Cone* together with its present place in breeding work:—

	1892	1897	1903
"Land" wheat of Skåne.	0701-(*a*) Very susceptible to rust. (*b*) Low yielder.		
	0516-(*a*) Very resistant against rust. (*b*) High yielder. (*c*) Excellent quality. (*d*) Straw very weak. (*e*) Head long and open. (*f*) Late Maturer. (*g*) Winter-hardy	0319-(Cone) (*a*) Same resistance against rust (*b*) Same yielding power. (*c*) Poor quality. (*d*) Straw rather stronger but still too weak. (*e*) Late Maturer. (*f*) Short, close cone-like head. (*g*) Winter-hardy	0319-× 0501* (*a*) Practically rust resistant (*b*) Very high yielder. (*c*) Only fair quality, yet much better than 0319. (*d*) Very stiff straw. (*e*) Winter-hardy.

A few fairly high yielding strains have been taken from the old Swedish varieties, but these have proven less hardy than the latter. This fact among others, has led to the conclusion that these forms are in many cases at least, the products of natural crossing between such high yielding but more delicate sorts as *Squarehead* and *English Stand-Up*, etc. The most noteworthy sort belonging to this category is *Sun*. (See p. 113).

From the imported English Squarehead wheat there have been isolated a number of strains which have proven even more winter-hardy than those already described (Grenadier and Extra Squarehead). Of these the sort known as *Pudel* (See Fig. 12) is the most valuable. While not so hardy as the old Swedish varieties, *Pudel* nevertheless combines a sufficient degree of hardiness with yield and other qualities to enable it to largely displace the old "land" sorts. The relationship between the above sorts in respect of hardiness together with the origin of each is indicated in the following diagram:—

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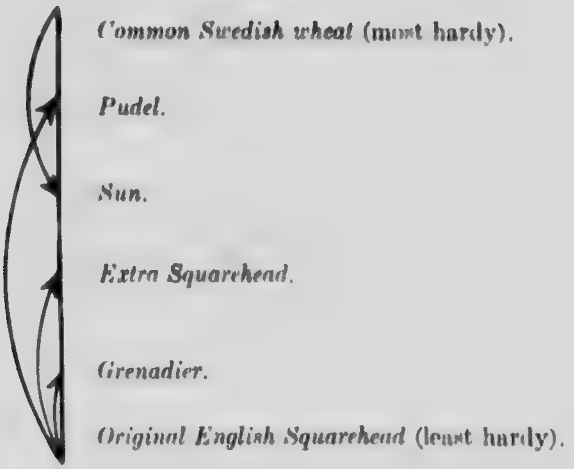
* This crossing has not only given the highest average yield for the past four years, most resistant against rust. It is still lacking in quality however, so will be subjected to repe in the hope of obtaining quality of a higher degree.


Common Swedish wheat (most hardy).
Pudel.
Sun.
Extra Squarehead.
Grenadier.
Original English Squarehead (least hardy).

From a Probstier wheat a sort known as *Bore* has been isolat[illegible] has proven almost as hardy as *Pudel.*

An examination of the above diagram reveals the interesting fac[illegible] hardier strains may sometimes be isolated from varieties which as a [illegible] are deficient in hardiness, than from varieties which excel in this resp[illegible]

The two pedigree sorts, *Bore* and *Pudel*, together with the mass-selected sort *Renodlad Squarehead*, are at present the three leading sorts in the wheat-growing districts of central Sweden.

These are described below as follow:—

Bore is a specially stiff strawed sort with high weight per bushel. While not so hardy as the common Swedish sorts it has nevertheless produced on the average of a series of years over 10% higher yield. In Skåne but not in middle Sweden, it is susceptible to yellow rust. By reason of [illegible] excell[illegible] showing in the north it has become widely distributed in such provinces as Östergötland, Södermanland, etc. It is still however, not sufficiently har[illegible] or early maturing to be recommended for those provinces lying north [illegible] Stockholm.

Pudel, as its name implies, belongs to the dense-headed, velvet-chaffed type. It represents the hardiest pedigree sort thus far taken from the less hardy imported varieties, marking an advance over *Bore* also in point of early maturity. On the average of ten years' experiments at Ultuna it has given about 19% higher yield than the sorts originally cultivated in that part of Sweden. In local trials it gave on the average, 10% higher yield than the latter sorts, although during certain severe winters the common Swedish varieties proved superior. It is decidedly stiffer in the straw than the common country sorts but not quite so stiff as *Bore.* In southern Sweden it is comparatively weak strawed but since it is not intended for these parts this is not a matter of importance. An objection to *Pudel* is the white color of its kernels and the readiness with which it sprouts and grows in the stook. Of all sorts tested *Pudel* is considered the worst in this respect. This is a matter of serious consequence in a country such as Sweden which suffers so frequently from rain during harvest.

The most striking characteristics of this sort, apart from the velvet nature of its chaff, are its broad spikelets containing from three to four kernels, the latter being white, roundish, plump and quite easily distinguished from other Svalöf sorts. This sort came on the market first in 1910.

In 1905 *Pudel* was crossed with the common old Swedish wheat known as *Swedish Velvet chaff* a sort resembling *Pudel* somewhat in character of chaff. The object of this cross is indicated later (See page 116). In 1910 ten of the most promising lines from this cross were in the preliminary test plots and six in the small "Marker-Sown" multiplication plots. Certain of these lines have excelled both parents in yielding tests conducted both at Svalöf and at Ultuna.

Photo by L. H. N.

FIG. XXVI.—Dr. Nilsson-Ehle taking notes on the most promising plot (5th generation) from the crossing *Pudel* × *Swedish Velvet chaff* Autumn wheat.

Renodlad (Selected) Squarehead is also one of the most popular sorts in middle Sweden, especially on the wheat soils of the Western Coast. At Svalöf it has been found too susceptible to a certain fungous disease (Leptosphæria herpotrichoides) but in the above mentioned districts it stands pre-eminent.

After the hard winters of 1899 and 1901 another mass-selection of the above sort was made which has given the highest average yield of all sorts tested at Ultuna since that time. The quality of this sort however, is only fira.

Photo by L. H. N.

FIG. XXVII.—Nilsson-Ehle examining segregation in the *Club* × *Pudel* wheat crossing on the basis of color of grain. *Club* is said to have 2 units for red color.

Fig. XXVIII. Table of Yields in pounds per acre, of hardy Autumn wheat sorts tested at Ultuna 1904-1909.*

Sort	1904	1905	1906	1907	1908	1909	Average Yield Per Acre (Pounds)	Per Cent Yield in Comparison with Swedish Velvet Chaff
Renodlad Squarehead	3474	3480	5408	3147	5238	3948	4056	131.5
Pudel	3206	3676	5001	3117	4964	3741	3950	128.0
Bore	3251	3266	4732	2523	4738	4168	3780	122.5
Swedish Velvet Chaff	2791	3189	3663	1811	4186	2863	3084	100.0

Among the leading sorts in southern Sweden at the present time are the following:—*Extra Squarehead II; Grenadier II; Sun; 0319 × 0501; Grenadier III (0502); 0551; Renodlad (Selected) Squarehead; Renodlad Grenadier* and the Danish sort *Tystofte Smaa (Small) wheat.*

Leading sorts in Southern Sweden.

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* From Sveriges Utsädesförenings Tidskrift, 1910, p. 73

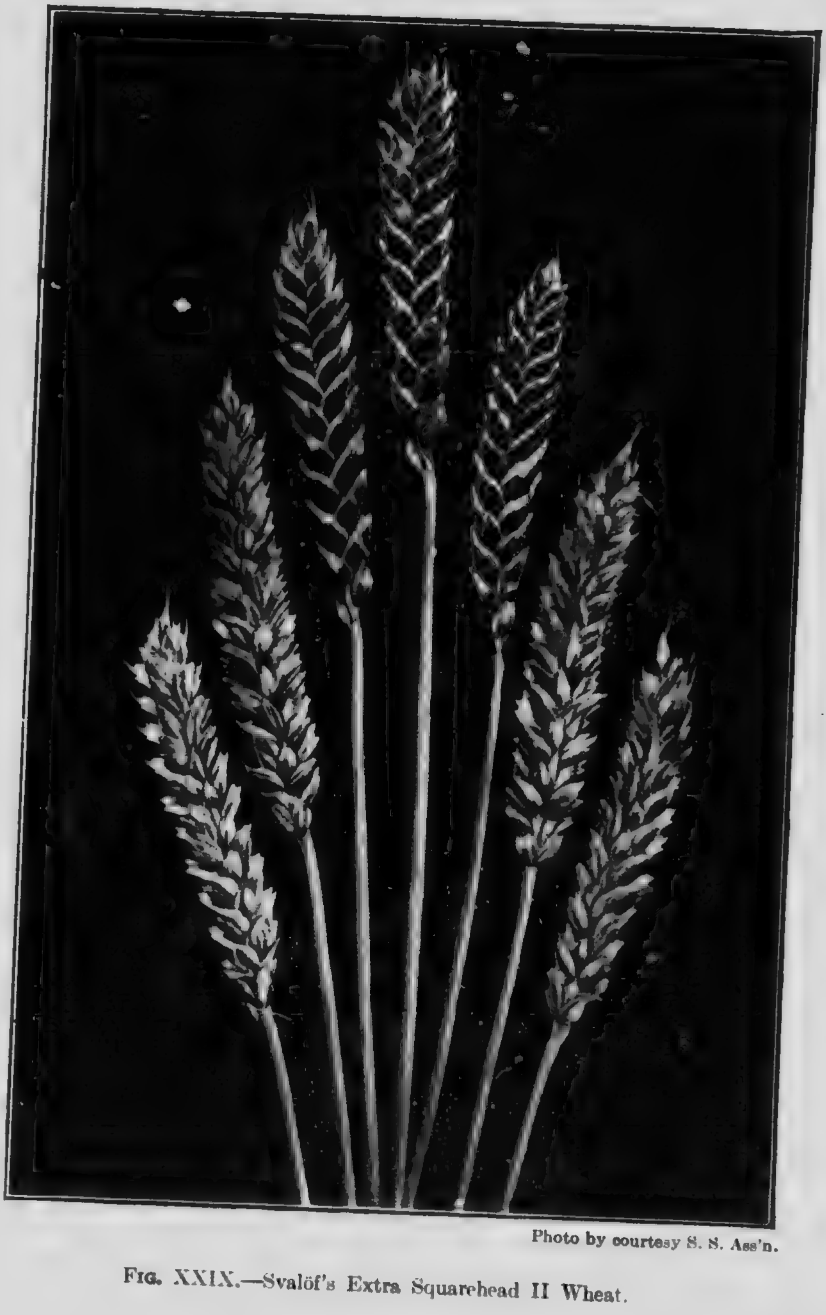


Photo by courtesy S. S. Ass'n.

FIG. XXIX.—Svalöf's Extra Squarehead II Wheat.

0290, Extra Squarehead II, is a crossing between *Old Extra Squarehead* and *Grenadier II* and excels both parents in that it combines the winter hardiness and the ability to resist rust of the former sort with the stiffer straw and higher yield of the latter. By reason of the above it has given on the average of four years' experiments at Svalöf and Alnarp about 18% higher yield than the *Old Extra Squarehead* and 8% more than *Grenadier II.* A sort combining the hardiness and yielding power of *Extra Squarehead II* had been diligently sought for earlier by selecting and testing many forms out of *Grenadier,* but without satisfactory results. Out of the hundreds of pedigree sorts tested none have combined so many good qualities and none are so generally popular among the wheat growers of southern Sweden as is the above crossing, although it is uncertain yet whether it can displace entirely *Grenadier II* in all sections.

Grenadier II, out of English Shirriff (a Squarehead sort) is the least winter hardy of all sorts produced at Svalöf, but is especially high yielding and stiff strawed and has been used extensively in crossing with others which are not so productive.

Another sort which at present promises to excel all others comes from the crossing *Cone* × *Grenadier II.* The interesting origin of this sort has already been described as have likewise its peculiar merits.

Sun wheat, although relatively early, stands among the very highest yielders at Svalöf. It is a little hardier than *Extra Squarehead II* but is not so strong in the straw nor so resistant against rust or smut as is the latter sort. A peculiar and not unimportant weakness of this sort is its tendency to germinate slowly in the autumn. This often results in a thin and unsatisfactory stand. Because of these shortcomings, crossings have been made between this and such other sorts as *Extra Squarehead II* and *Grenadier II.* This sort was given over to the Seed Company in 1908 and will probably come on the market in 1911.

Grenadier III is one of several lines selected from the old pedigree sort *Grenadier II.* It is not noticeably different from the latter in morphological character but seems to be a little more productive and at the same time quite as winter hardy.

0551 is another line selected in 1903 from *Grenadier* which is decidedly more winter hardy than the latter sort. It has stood among the highest yielders since taken into the tests and in 1910 gave the highest yield of all sorts under consideration but was rather weak in the straw. The two last mentioned sorts are excellent illustrations of the possibilities of improving upon old pedigree wheat sorts.

The following table indicates the relative yielding power of the leading sorts at Svalöf for the years indicated. The old *Swedish Velvet chaff* is used as a basis of comparison, its value being placed at 100.

Fig. XXX.—Table of yields of leading Autumn wheat sorts of Svalöf 1890-1909 (22, p. 23).

Stockbook number and name of Sorts.	No. of years tested	Average yield per acre in pounds.		Yield in % compared with the Swedish Velvet Chaff.		Weight per Bushel (lbs.)
		Grain	Straw	Grain	Straw	
0290, Extra Squarehead II (Extra Squarehead × Grenadier).	4	3600	6362	135·6	125·9	59·2
0501, Grenadier (Pedigree sort)...	13	3400	5823	128·5	115·2	59·6
0406, Bore (Pedigree sort).......	13	3252	6303	122·5	124·7	60·5
0200, Renodlad (Selected) Squarehead (not a pedigree)....	13	3223	5483	121·4	108·5	59·2
0315, Pudel (Pedigree sort)......	9	3076	5725	115·9	113·3	59·5
0203, Extra Squarehead (Pedigree)	11	3051	6024	114·9	119·2	58·7
Swedish Velvet Chaff......	19	2655	5053	100·0	100·0	...
Swedish Club wheat.......	13	2606	5968	98·2	118·1	59

Pedigree plots under investigation.

In the experimental grounds in 1910 there were between 300 and 400 pedigree plots of autumn wheats, practically all of which belonged to different crossings. Each of these crossings was made with a definite practical object in view. According to the present system these plots are numbered consecutively. Thus in 1910, the first plot bore the field number 132 and the last 491 as follows:—

Field Numbers in 1910:

132 = 0234 Selected Squarehead.
133 = 0290 Extra Squarehead II.
134 = 0406 Bore.
135 = 0415 Sun.
136 = 0501 Grenadier II.
137 = ... Tystofte Smaa wheat.
138 = ... Tystofte Stand wheat.
139–144 = *0290* × *Stand-Up* (2nd generation).

Object of cross.—To combine the higher yield which the *Stand-Up* is capable of giving during favorable years with the greater hardiness of *0290*. Also to combine the shorter straw of *Stand-Up* with the stronger structure of *0290*. The latter sort is normally strong, but is too long to allow of maximum strength.

145–146 = *0501* × *Stand-Up* (2nd generation).

Object.—Same as in last mentioned crossing.

147–163 = *0415* × *0290* (2nd generation).
Object.—To combine the greater hardiness of the former with the stiffer straw and greater resistance against rust and smut of the latter.

164–167 = *Tystofte Smaa* × *0501* (2nd generation).
Object.—To combine the greater hardiness and earlier maturity of the former with the stiffer straw of the latter. A higher yielding sort than either parent is also looked for.

168–169 = *Tystofte Stand* × *0290* (2nd generation).
Object.—To combine the greater rust resistance of the former with the greater hardiness and higher yield of the latter.

170–173 = *0234* × *0501* (2nd generation).
Object.—To combine the greater hardiness of the former with the greater yield and stiffer straw of the latter.

174–188 = *0406* × *0415* (2nd generation).
Object.—To combine the greater hardiness and quality of the former with the higher yield of the latter.

189–193 = *0406* × *0501* (2nd generation).
Object.—To combine the greater hardiness of the former with the higher yield of the latter.

194 = *0501*, Grenadier II.

195 = *0415*, Sun.

196–303 = *0501* × *0415* (3rd generation).
Object.—To combine stiffer straw of the former with greater hardiness of the latter.

304–323 = *0501* × *0290* (3rd generation).
Object.—To obtain a higher yielding sort than 0290 with the same hardiness.

324 = *0501*, Grenadier II.

325 = *0290*, Extra Squarehead II.

326 = Tystofte Smaa wheat.

327–365 = *Tystofte Smaa* × *0290*, Extra Squarehead II (3rd generation).
Object.—To combine the greater rust resistance and earlier maturity of the former with the stiffer straw and the greater winter hardiness of the latter. This crossing has given very promising results.

366 = *0234*, Out of Renodlad Squarehead.

367 *0406*, Bore.

368–424 = *0234* × *0406* (3rd generation).
Object.—To combine higher yield of the former with higher quality of the latter.

425 = *0315*, Pudel.

426 = Swedish Velvet Chaff.

427–480 = *0315* (*Pudel*) × *Swedish Velvet Chaff* (5th generation).
Object.—To combine the stiffer straw and higher yield of the former with the better quality and greater hardiness of the latter.

481 = *0501*, Grenadier II.

482–491 = New lines from Grenadier II taken from Seed Company's field.

492 = *0502*, Grenadier III. Plot of 48 rows each row planted with 30 kernels, and each lot of 30 kernels taken from a single plant. (Seven of the best rows were taken for further comparison in small plots in 1911).

Small marker-sown multiplications.

495–498 = *0290*, Extra Squarehead II (new lines).

499–504 = *0315*, Pudel × Swedish Velvet Chaff.

The above review of the work in Autumn wheat breeding in Sweden clearly indicates that substantial progress has been made. As was pointed out in the beginning the most pressing needs of the growers of Autumn wheat were for sorts combining higher yield, stronger straw and greater resistance against disease with the hardiness and quality of the common "acclimatized" varieties of the country. This need has been partially realized. A number of excellent pure-lines or strains have been isolated, which in themselves have proven superior to the varieties hitherto grown. By crossing certain of these strains together as well as with certain old varieties still further progress has been obtained, and much is still looked for. While the returns per acre have materially increased by the use of better sorts, the area devoted to the production of this crop has likewise extended on account of the availability of sorts better suited to different conditions. Where formerly Rye constituted the principal crop in many districts, wheat can now be grown with greater profit. The great[illegible]rease in the wheat growing area is in Malmöhus county (län) situate[illegible] most southern part of the country.

2. Spring Wheat Breeding

The area devoted to the cultivation of spring wheat in Sweden is comparatively small, representing only 1·6% of the total area devoted to all field crops. This is due to the larger yields obtained from autumn sorts, and to the greater suitability of the latter for most districts. In certain districts, notably on sand soils where autumn wheat does not thrive, spring wheat can be grown with very good success, and in such localities occupies a place on practically every farm. Work at Svalöf with this crop has been carried on with a view to producing more suitable and profitable sorts for the strictly spring wheat districts.

When this work was undertaken there existed in the country several common types which were characterized by very early maturity, small kernel, narrow open head, rather weak straw and rather high susceptibility to rust.

Importations of foreign sorts were made and while practically none of these proved superior to the old sorts of the country some were used to good advantage in breeding work. The German sort *Kolben*, resembling *Red Fife* closely in character, excelled the Swedish sorts in ability to resist rust, in strength of straw and in size of kernel. It consequently became widely distributed throughout the southern parts of Sweden but was too late to thrive to advantage farther north. In the greater part of Sweden, particularly in the spring wheat ar[illegible]y maturing sorts are imperative owing to the prevalence of early summe[illegible]night frosts. For this reason the greater part of line-breeding work is now confined to the early Swedish varieties. A large collection of different stocks of these varieties has been obtained from farmers and others living in the northern and western provinces and efforts are being put forth to discover within them, strains of superior value. While these varieties seem to possess very few distinct botanical forms, yet recent work in line-breeding has revealed physiological differences in sufficient measure to warrant a thorough analysis of the most promising stocks.

Among other foreign importations, the German sort *Emma* has given a couple of strains of considerable value, viz., *Pearl* and *No. 0201*. *Pearl* has given about the same average yield in Skåne as has *Kolben* but has a stiffer straw. It is unfortunately, more susceptible to rust and is too late in maturing for points outside of the Southern province.

No. 0201 gives, on the average, about 10% higher yield than either *Pearl* or *Kolben* while in strength of straw and date of maturity it stands practically on a par with the former. In quality it is inferior to *Pearl* so has been crossed with this sort. The above two sorts, although taken from the same old variety (Emma) are essentially different in respect of certain characters.

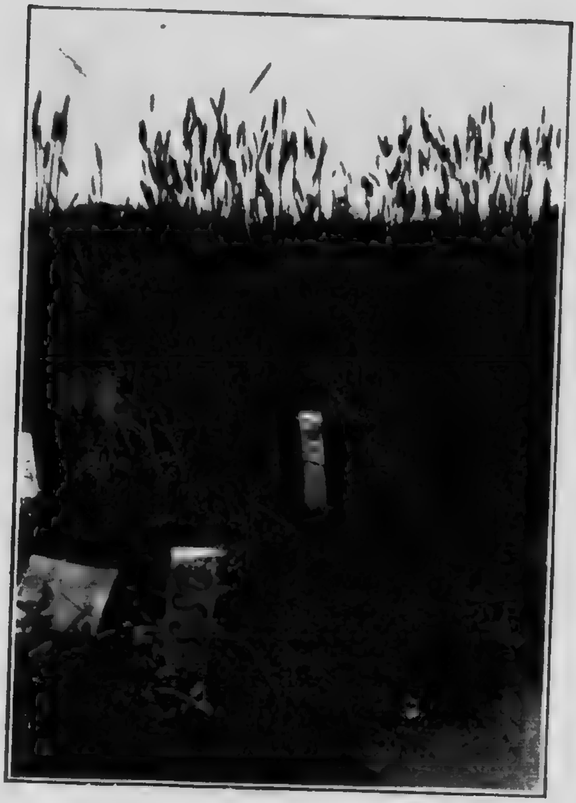


Photo by L. H. N.

Fig. XXXI.—Spring Wheat cultures, Nos. 102, 103 and 104 (1910) from the crossing 0201 × Pearl. Plot 104 on the right, ripened earliest and was exceedingly promising in other respects.

The case of the two sorts *Pearl* and *No. 0201* affords another interesting example of the great differences which may exist in practical qualities between strains taken out of the same old variety, as well as the possibility of bringing such sorts together to form superior combinations. The differences between these sorts as well as their origin and subsequent treatment are illustrated in the following graphical manner:—

Emma, too late,
not at all suitable
for Sweden.

No. 0201
High yielder
Rather stiff straw.
Poor quality.

Pearl.
Not so high a yielder.
Very stiff straw.
Good quality

0201 × Pearl

From *Kolben* a single strain, *No. 0702*, has been isolated which is regarded as slightly superior to the original.

Two American sorts *Red Fife* and *Duluth* have been tested. From the latter several lines have recently been taken but it is yet too early to anticipate results.

The *Brown Schlanstedt wheat* which, in the province of Saxony, Germany, competes with the best autumn sorts in yield, has been thoroughly tested in Sweden but found to be too late for that country. It is therefore proposed to cross this sort with such sorts as *Kolben* and *Red Fife* with the hope of combining some of the high yielding properties of the former with the earlier maturity of the latter.

Approximately 200 pedigree plots of spring wheat representing the products of five different crossings, all in the 4th generation, were under study in the Experimental grounds at Svalöf in 1910. These were as follow:—

1. *0201* × *Pearl.* Object — to combine the good quality of *Pearl* with the high yield of the former.
2. *Pearl* × *Kolben.* Object:—to obtain a sort combining the earliness and rust resistance of *Kolben* with the very stiff straw of *Pearl.*
3. *0201* × *Kolben.* Object:—to obtain a sort combining the rust resistance and quality of *Kolben* with the yield of *0201*.
4. *Kolben* × *0729* (a brown-chaffed, awned sort). Object:—to obtain an earlier ripening sort of the *Kolben* type for the spring wheat districts of the North.
5. Kolben × *0740* (a common variety from Dalarne). Object:—the same as No. 4.

3. Oat Breeding.

During the first years of the Association's existence the work with oats as with wheat consisted in testing a large number of Swedish and foreign sorts in order to obtain the best material as foundation for further improvement. From among these sorts the following three seemed most worthy of cultiviation:—

1. *Probstier* (sort commonly grown in the Baltic region).
2. *Ligowo,* a pedigree sort obtained from Vilmorin of France and suitable for later districts where an earlier sort is required.
3. *Black Tartarian,* for those districts in which black sorts are preferred.

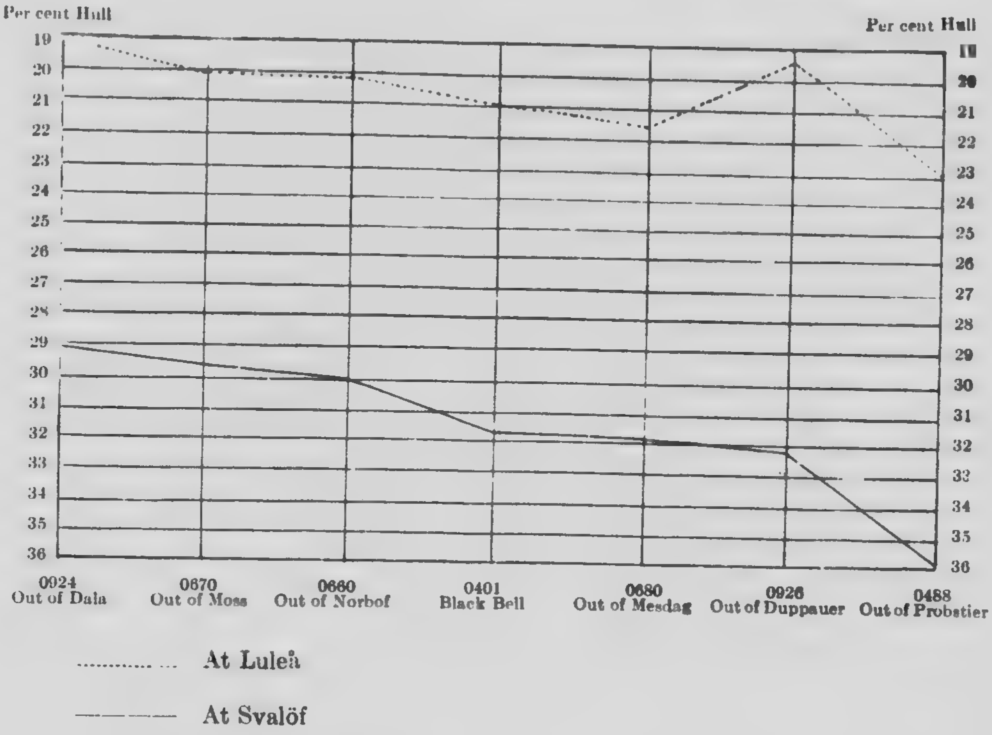
In oat breeding work the principle considerations are: *Yield, quality, strength of straw, resistance to disease and ability to thrive on a reasonable variety of soils.* In the central and northern districts earliness is one of the most important qualities. The performance of the different sorts in regard to these points is striking and indicates that a 'universal' oat sort is not to be expected in a country presenting such a variety of conditions as is found in Sweden. This fact was already recognized at Svalöf from the beginning and the question of local trials as a means of determining the suitability of sorts for a given locality has always been regarded as one of great importance.

Quality in Oats.

A comparison of results at Svalöf and Ultuna affords an interesting study of the effects of soil and climate on oat sorts and also serves to indicate some of the difficulties which confront the breeder. The quality of oats, which is judged on the basis of per cent hull, weight per 1,000 kernels, hectolitre weight (weight per 2.85 bushels) and per cent double kernels, is found to be better in the north than in the south. As regards per cent hull there is found a difference of several per cent in favor of the most northern station at Lueål. Other experiments are available to show that the further north a sort can be grown the thinner becomes the hull. The accompanying table indicates more clearly the behaviour of the different sorts in this regard:—

Per cent Hull.

Fig. XXXII.—**Per cent Hull in oat sorts tested at Svalöf and at Luleå in 1904.**



The above diagram reveals the parallel behaviour of the different sorts in respect of per cent hull in the two places indicated and shows that sorts grown at Luleå in 1904 were approximately 10% thinner in the hull than those grown at Svalöf during the same year.

Weight per 1000 kernels

Of all sorts tested at Svalöf and Ultuna Ligowo stands first in thinness of hull. As regards *weight per 1,000 kernels* experiments again indicate the superiority of grain grown at the northern station. Here again Ligowo heads the list.

Weight per bushel.

The *weight per bushel*, while important, is liable to be misleading. An excellent example is found in the case of the *English Potato oat* (Kubb). As will be noticed in the following table this variety stands at the head of the list in weight per bushel, but at the same time possesses the very highest per cent hull. *Nigger*, on the other hand, has a low weight per bushel with a low per cent hull. That no definite relation exists between weight per bushel and per cent hull seems clearly proven.

Weight per Bushel in comparison with Per Cent Hull in oats tested at Svalöf.

Sort	Weight per measured Bushel.	Per cent. hull.
0701—English Potato Oat	42·26 lbs.	32·25
0386—Gold Rain	40·22 "	27·50
0353—Ligowo	39·95 "	26·80
0329—	39·60 "	25·70
0926—Duppauer	39·37 "	33·70
0355—Victory	39·29 "	28·70
0302—White Probstier	39·06 "	27·60
0301—Hvitling	38·98 "	28·20
0300—Awnless Probstier	38·21 "	27·00
0275—Nigger	38·16 "	23·90
0401—Black Bell I	37·44 "	31·50
0450—Great Mogul	35·60 "	31·25
0101—	34·47 "	27·25

An examination of the table of yields (See page 129) affords further proof that no relationship exists between the productivity of a sort and its weight per bushel. Thus the *English Potato Oat*, although weighing the most per measured bushel, is not included in the table of yields as it was found deficient in respect of yield as well as of quality. *Awnless Probstier*, although at the foot of the list of White oats in weight per bushel, stands both among the best yielders and among those possessing the best quality (thinnest hull). Weight per bushel is influenced most by shape of kernel. Short plump grains pack more closely and therefore weigh more than do those which are longer and more slender, although they are not necessarily of greater value. While the weight per bushel of different sorts affords little indication of their respective values, the weight of different *lots* belonging to the same sort and grown under different conditions may constitute an important basis of valuation. In describing the different sorts offered the public, the Swedish Seed Company never makes use of the weight per bushel.

Double kernels.

The *percentage of so-called "Double Kernels"* in oats is another point of importance. A double kernel consists of the secondary kernel or spikelet enfolded in the glume of the primary spikelet, the kernel of the latter being undeveloped. The development of double kernels is different in different sorts and under different conditions. *Gold Rain*, for example, produces as a rule, very few double kernels whereas *Hvitling* and *English Potato* are characterized by a relatively high percent. At Svalöf the per cent double kernels in all sorts is usually higher than at Ultuna as shown in the following table. The results here given represent the average of a series of years.

		Per cent Double Kernels.	
		Svalöf	Ultuna
0386	Gold Rain	0·3	0·3
0329		0·8	0·5
0355	Victory	0·9	0·9
0302	White Probstier	1·0	0·8
0353	Ligowo	1·3	0·7
0300	Awnless Probstier	1·3	0·7
0450	Great Mogul	1·6	1·9
0401	Black Bell	1·8	1·1
—	Black Tartarian	2·2	1·8
0301	Hvitling	3·3	1·7
—	English Potato	4·4	3·5

As explained elsewhere double kernels may be developed as the result of sterility of the primary kernel, a condition which frequently arises through crossing two sorts of widely different character.

Actual improving work with oats may be said to have begun at Svalöf in 1892, since which time great numbers of varieties and pure lines have been investigated. From the Probstier group has been obtained the best material, this group furnishing a wonderfully rich collection of different strains. The most prominent of these strains are *0355* (*Victory*), *0386* (*Gold Rain*) and *Awnless Probstier* (a mass-selected stock). Although, as will be seen later in the table of yields, these sorts excel only slightly, the best old unimproved *Probstier* variety.

Leading white oat sorts.

Victory is at present the leading white oat sort yet produced at Svalöf. It is a stiff strawed sort of medium height with stiff upright but rather short panicle giving little indication of its high yielding capacity. The spikelets are as a rule two-kernelled and of medium size, while the glumes are relatively small and short. In stooling ability it is classed as relatively good. This sort has been found most suitable for the southern and western provinces and on clay or clay-loam soils. It came on the market for the first time in

1908 since which time it has obtained an unusually wide distribution. In other countries, notably Holland and Canada* this sort has given excellent results in experiments thus far conducted.

Gold Rain presents a remarkable combination of good qualities being relatively early yet a high yielder; it is very strong in the straw (See Fig. 33), gives the highest weight per bushel of all sorts tested, is thin in the hull and is moreover, capable of thriving on a surprising variety of soils. The panicle is small and the kernels golden and not specially attractive in appearance. On the average of ten years' trial at Ultuna it has stood almost on a level in yield with *Victory*, but is recommended in preference to the latter for the white oat districts of middle Sweden on account of its earliness and suitability for poorer soils.

Awnless Probstier as already explained, is a mass-selected sort yet it is among the most productive of all sorts tested. It is especially valued because of its ability to thrive under a great variety of conditions.** Like *Gold Rain* it is a yellow or golden-grained sort and often difficult to distinguish from the latter. It is a good stooler with tall but not specially strong straw.

Many new lines were selected from old Probstier stock between 1903 and 1906, and of these not less than seven have been carried to the large comparative trials where results thus far seem to indicate that one of these at least may mark an advance over *Victory* in yield.

Ligowo, obtained originally from Vilmorin of France, has proven a valuable sort for certain soils and districts in Sweden. It is specially valued for its earliness and high quality being yet unexcelled in regard to the latter. It thrives best on fertile, vegetable moist soils. On dryer, higher soils it is rather uncertain, the straw often being shorter and the kernels inclined to thresh out easily when mature. The kernels are pure white, extra short and plump with a low per cent hull and are usually awnless. It is a thin stooler, with straw strong and of medium height.

Several lines have been taken from this sort, but none can be said to mark any advance over the original. In the light of present conceptions of the phenomenon of variation the failure to discover better strains in Ligowo is due to the fact that this sort is already a pedigree and does not, therefore, contain hereditary variations.

Svalöfs' Dala (0924) is a pedigree sort out of the old variety Dala, commonly grown in Dalarne. This is a very early sort coming between *Gold Rain* and *Black Mesdag* in this respect. It is found most suitable where sorts such as *Gold Rain* can not be relied upon to mature, and has shown itself superior in yield, but more especially in quality, to the old variety from which it was taken. It is, however, much too weak in the straw, so has been crossed with *Gold Rain* (See Fig. 33).

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* See Canadian Seed Growers' Association, 6th Annual Report, 1910, p. 86.

** Årsredogörelse, Allmänna Svenska Utsädesaktiebolaget, 1910, p. 15.

A pedigree sort known as *Yellow Nasgaard*, recently introduced from Denmark, has proven exceptionally promising at Svalöf, and may possibly excel *Victory* under certain conditions. This sort was selected from *Danish Island* in 1899, by Vestergaard of the Abed Station, Denmark, and despite all efforts to obtain a better sort, it can still be said to hold first place on the best soils in that country, although on poorer soils it is said not to be able to compete with the old Mother Sort (26, p. 654). On the average of the past five years' trials at Svalöf, *Nasgaard* has given the highest yield of all sorts, although a later pedigree (0318) from *Probstier* has, during the three years it has been in the tests, proven more productive.

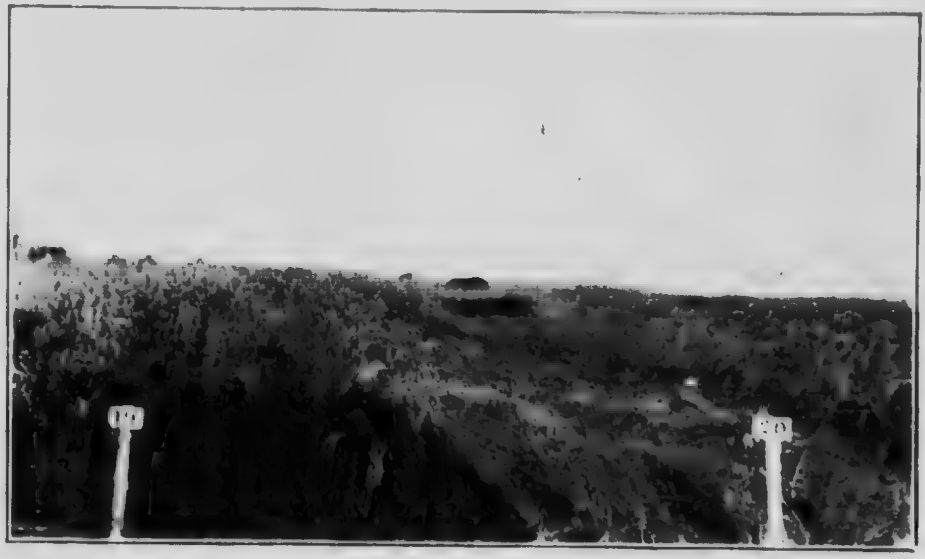

Photo by L. H. N.

Fig. XXXIII.—Oat plots—Gold Rain (No. 19) and *Svalöf's Dala*, 0924 (No. 20) showing relative strengths of straw.

The *American Banner*, which has been among the most productive sorts in Denmark for many years, has also proven very promising at Svalöf. It is the present intention to make a pedigree analysis of this sort with a view to isolating, if possible, a superior strain.

Leading black oat sorts.

In certain parts of the district known as *Middle Sweden* are large tracts where black varieties of oats are preferred. The common sorts of the country were grown exclusively in these places up to about 25 or 30 years ago when the *Black Tartarian* was introduced. On account of the stiffer straw of this sort it came to displace very largely the old sorts, but with the advent of new improved sorts from Svalöf it in turn, was forced to occupy a minor position.

Breeding work with Black oats intended for Middle Sweden is now largely concentrated at the Station at Ultuna under the supervision of the superintendent, Mr. A. Elofson. The more prominent black sorts now under investigation are *Black Bell I*, *Black Bell II*, *Great Mogul*, *Common Roslag* and *Fyris*. Short descriptions of these sorts are submitted as follow:

0401, Bell I.—Stiff strawed and quite early ripening. On stiff clay soils in the black oat districts it is frequently excelled by the common country sorts, but on heavy vegetable soils it often gives considerably higher yields than the latter.

0408, Bell II.—Said to be a natural crossing between *Bell I* and *Gold Rain*. In yield as well as in quality this sort has proven somewhat superior to *Bell I*, which it has come to largely displace. In type of plant it closely resembles *Bell I* from which it is distinguished in the field by its smaller glume which, at maturity, is not so bell-like in appearance. The kernels are somewhat thinner in the hull and higher in weight than those of common *Bell I*. This sort first came on the market in 1909.

A peculiarity of both *Bell I* and *Bell II* is the unusual development of sterile flowers or spikelets at the base of the panicle.

0450 Great Mogul.—A pure line from Black Tartarian. Panicle very large and long, often overhanging; spikelets large with long, close light-colored glumes. Kernels tolerably large, long, well filled, plump, thin hulled and long-awned. Plants very tall with unusually stiff straw. Ripens late so is not recommended for provinces north of Stockholm. Thrives best on clay and sandy soils. Is the best black sort yet produced for the southern parts of the black oat districts, but is not suitable for the later districts. For this reason it has been crossed with *Bell II*. This sort came on the market for the first time in 1901.

The *Common Roslag* is an old sort peculiar to the district of Roslagen in Middle Sweden and distinguished from the other black sorts of the country by its more upright and richer panicle. In trials at Ultuna, on stiff clay soils, it has proven to be the highest yielder of all black sorts tested, but by reason of its lateness it has been somewhat excelled on the average of a number of years' tests by *Fyris* (Improved Roslag), which is a strain of this variety. Unlike *Probstier*, *Roslag* has shown a dearth of different forms. By the system of line-breeding now in vogue however it is hoped that superior strains may eventually be isolated. Because of the weakness of its straw it has been crossed with *Bell II*.

01004, Fyris.—As just explained this sort is a strain out of the Common *Roslag* variety, and is now regarded as of special value for stiff soils where the latter is too late. While this sort shows but little improvement over the mother sort in yield of grain, and is actually lower in straw production, yet it is found to be more than a week earlier and also of better quality (4% less hull and 2% fewer double kernels) than the latter. It is still quite as weak strawed as the original mixed sort and has therefore been crossed with *Bell II* and *Great Mogul*. Came on the market first in 1911.

Three forms resulting from a natural crossing between *Black Tartarian* and *Probstier*, and combining the high yield of the latter with the strong growth of the former, promise to become of special value for the production of green fodder. One of these forms, having the stock-book number *0193*, gave in 1905 and 1910 the highest yield of grain of all sorts tested, but during the intervening years its behavior was less satisfactory.

A sister sort *0298*, which also inherited some of the high yielding properties of *Probstier* and at the same time possesses a more luxuriant vegetation than even *Black Tartarian* has again been crossed with the latter. This is another good example of repeated crossing.

Early sorts for the far north.

For the extreme northern sections where oat growing is at all possible a few very early sorts have been brought out. The highest yielder of these thus far tested at Luleå is Number *0668*, a pedigree out of a common northern variety. The quality of this sort, however, is low, so it has been crossed with *Ligowo* (0353) with a view to obtaining in combination with its own early maturity, some of the high quality of the latter sort. An early line from this cross (*0353* × *0668*) has given promising results in experiments conducted in Northern Sweden, the quality being excellent. This line will come on the market in the very near future.

0670, *Svalöfs' Moss* oat, a pure line taken from the common *German Moss* variety, is, like the latter, most useful in such districts and under such conditions as demand the very earliest ripening sorts. On the wet cold peat soils of Sweden this sort has as yet been unsurpassed, although under more favorable conditions it cannot compete in yield with the sorts previously discussed. The only advantage claimed for this sort over the common variety from which it was taken is its purity. Not infrequently, however, has the common composite variety been awarded a higher place than the pedigree sort. In order to obtain a sort combining stiffer straw and higher yielding capacity with the very early maturity of this sort it has been crossed with *Gold Rain*. *0670* came on the market in the spring of 1911.

Black Mesdag, a pedigree sort obtained from Vilmorin of France, resembles the foregoing sort closely in practical qualities. In weight per bushel it is somewhat higher, but in proportion of kernel to hull it is lower. It is also inclined to thresh out easily at maturity.

0660 is a pedigree sort out of a variety commonly grown in Northern Finland. It is a very early sort with very stiff evenly developed straw but with small light kernels.

0353 (*Ligowo*) × *0660* is a crossing which aims to unite the very early ripening properties of the latter with the high quality of the former. A line from this crossing has given excellent results in trials conducted in the northern regions, and will come on the market at a very early date.

Each of the sorts above described as well as certain foreign sorts under investigation, thirty-six sorts in all, occupied a place in the large comparative trial plots on the Experimental grounds at Svalöf in 1910. In addition to these were sixty preliminary trial plots, 338 small pedigree plots and five plots devoted to the multiplication of élite stocks. The field numbers for these plots run consecutively from 37 to 441 thus:—

Preliminary trials with oats in 1910.

A.—Machine sown (two plots of 1 metre × 12.5 metres each, for each number).

37–60—Different lines from the *Probstier* group.
61–66—Different lines from the *Roslag* group.

B.—Sown by hand with the "marker" (two plots, each .75 metres × 6 metres, for each number).

67–98—From the crossing *Bell II* × *Great Mogul* mentioned below and aiming to isolate the most valuable line.

Pedigree plots of oats under investigation in 1910.

99–151 = Pedigrees from older or newer Svalöf or other sorts.

152–156 = *0355* (Victory) × *0318*—2nd generation. Two high yielding sorts crossed to obtain still higher yield.

157–159 = *0355* × *0353* (Ligowo)—2nd generation.
Object.—To obtain a sort combining the high yield of *0355* with the higher quality and earlier maturity of *0353*.

160–163 *0355* × *0386* (Gold Rain)—2nd generation.
Object.—To obtain a white kernelled sort possessing the early ripening properties of *0386*.

164–168 = *0355* × *Yellow Nasgaard*—2nd generation.
Object.—Two high yielding sorts crossed to obtain a still higher yielding sort.

169 = *Nasgaard* × *0355*—2nd generation.
Object.—Same as in last crossing.

170–172 = *0355* × *Strubes*—2nd generation.
Same as last two.

173–174 = *0318* × *Strubes*—2nd generation.
Object.—Same as last three.

175 = *0353* × *0386*—2nd generation.

176 = *0408* × *01004*—2nd generation.

127–179 = *0450* × *01004*—2nd generation.

180–232 = *0298* × *0210*—3rd generation.
Object.—To obtain a stronger growing green fodder sort with higher yield of grain than the last mentioned parent.

233 = *0298*—From a natural crossing between *Black Tartarian* and *Probstier.*

234 = *0210*, Black Tartarian.

235 = *01006*, Roslag.

236 = *0408*, Bell II.

237–260 = *01006* × *0408*—3rd generation.

Object.—To combine the high yield of grain and straw of the former with the stiffer straw and earlier ripening of the latter.

261 = *0408*, Bell II.

262 = *0450*, Great Mogul.

263–357 = *0408* × *0450*—5th generation.

Object.—To obtain a sort combining the good qualities of the latter with the earlier ripening of the former.

358 = *0386*, Gold Rain.

359 = *0670*, Svalöf's Moss.

360–401 = *0386* × *0670*—4th gener

Object.—To obtain a so [illegible] ing as many of the former's good qualities as possible with the still earlier ripening of the latter.

402 = *0386*, Gold Rain.

403 = *0924*, Improved Dala.

404–436 = *0386* × *0924*—4th generation.

Object.—To obtain a sort combining the stiff straw and high yield of *Gold Rain* with the earlier maturity of *Dala.*

437 = *0408* × *0450*—(Sown by hand with the marker).
438 = *01008*, Pedigree out of *Roslag.*
439 = *01009*
440 = *03002*
441 = *03003*

Stock Multiplications.

Summary of present work in oat breeding.

By way of summary the present work in oat breeding in Sweden may be said to be directed along the following three main lines (48, p. 258), thus:—

1. *For southern Sweden's white oat districts:—*

(a) Line-breeding from the old *Probstier* group on a more extensive scale than heretofore and

(b) Crossing the best pure lines from the above group with each other.

2. *For Middle Sweden's black oat districts:—*
   (a) Line breeding from the common *Roslag* and
   (b) Crossing the best available black sorts with each other.

3. *For the later districts:*—Crossing the very earliest available sorts with others which are higher yielding and yet tolerably early, such as *Gold Rain* and *Ligowo*.

The following table gives the average yields of the leading white and black oat sorts at Svalöf and Ultuna respectively, for the years indicated:—

Fig. XXXIV.—Table of Yields in pounds per acre, of White Oats at Svalöf 1900-1909 (22 p. 26).

Names and Stock-book number of the Sorts.	No. of years under trial.	Average yield per acre.		Yield in comparison with that of Awnless Probstier.		Average weight per Bushel.
		Grain (lbs.)	Straw (lbs.)	Grain (%)	Straw (%)	Lbs.
0355, Victory (Pedigree out of Probstier)	9	3420	4350	104·9	104·5	39·29
— Danish Island (Old unselected Probstier oat)	4	3313	4088	101·6	98·3	. . .
0383, Gold Rain (Pedigree out of Probstier)	9	3295	4355	101·1	104·7	40·22
0100, Awnless Probstier (Mass-selection)	9	3260	4160	100·0	100·0	38·21
0301, Hvitling (Pedigree out of Probstier)	9	3242	4195	99·5	100·9	38·98
0353, Ligowo (Pedigree originally from Vilmorin)	9	3233	4168	99·2	100·2	39·95
0302, White Probstier (Pedigree out of Probstier)	9	3198	4302	98·1	103·4	39·06

Fig. XXXV. Table of yields of Black Oats at Ultuna 1897-1909 (22 p. 28).

Names and Stock-book number of the sorts.	No. of years under trial	Yield per acre in pounds. Grain	Straw lbs.	Yield compared with Bell I. Grain %	Straw %
0104. Fyris (Ped. from common Roslag)	6	2408	3220	114·0	90·0
Common Roslag.............	5	2387	3533	113·0	98·8
0408. Bell II (Bell I × Gold Rain).......	6	2278	3303	107·8	92·3
0450. Great Mogul (Ped. out of Black Tartarian)....................	12	2137	3758	101·1	105·0
**0401*. Bell I....................	12	2113	3578	100·0	100·0
Mesdag......	5	1793	2676	84·8	74·8
Black Tartarian	11	1784	3071	84·4	85·8
Excelsior.	3	1752	2613	82·9	81·3

The foregoing tables, it must be admitted, do not show that the common sorts of the country have been greatly exceeded in yield by the best pure strains thus far produced. It must be remembered, however, that many years of patient effort have been required in order to ascertain the capabilities and peculiarities of the best old varieties and their constitutents. With the knowledge which has thus been acquired, together with the excellent material which is now available, the present hope is to combine through crossing a greater number of desirable characters than has yet been found in a single strain. The varieties *Bell II* (Bell I × Gold Rain), *0353 × 0668* and *0353 × 0660* above described, indicate that progress has been made already by this means, while the future of many other crossing products now under investigation, is hopeful.

4. Barley Breeding†

Barley is cultivated in Sweden chiefly in the provinces of Skåne, Öland, Gotland, Östergötland, Upland and Dalarue. In all districts except in Norrland (Northern Sweden), where only the very earliest six-rowed sorts are grown, the two-rowed sorts are preferred as these usually yield much more than do the six-rowed and also produce a much plumper, finer and more uniform kernel, for which reason they are more popular with the brewer. At the time the Association at Svalöf was organized there were to be found in Sweden chiefly native sorts, apart from the English variety *Chevalier* which had been introduced by the brewers in the early eighties. The sort commonly cultivated in Middle Sweden was the native variety known as *Imperial* or often as *Plumage* barley on account of the peculiar "plume-like" character of awn development.

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* Will probably be withdrawn from the market in the near future.

† The data here given on the work with barley as well as that presented later on work with pease, have been obtained from publications by Tedin. These include annual reports and special articles together with reviews of the progress made during different periods.

From 1886 until 1892 the principal barley work consisted in comparing in the large yielding trials and analyzing in the laboratory, many different native and foreign sorts. *Chevalier* was at this time considered superior to all other sorts both in yield and quality, although it was weak in the straw. Not less than twenty different stocks of this variety were tested in the large trials where results showed that it is, after all, only an average yielding sort as other sorts, notably the *English Prentice*, excel it.

Of all barley sorts and stocks tested during these first years only three were subjected to the old system of mass-selection. These were *Chevalier* from Lerchenburg, Denmark, *Swedish Plumage* and *English Prentice*.* The results obtained with these sorts have already been described (See p. 21).

When the pedigree system was first applied (1892) it quickly served to isolate a large number of different strains, the most promising of which came into the large comparative trials in 1894. During the following ten years from 40 to 50 different strains were tested, of which number four were six-rowed and the remainder two-rowed. Of the latter about half belonged to the Nutans type and half to the Erectum. (For definition of these types see page 133.)

The question of brewing barley has received much attention in Sweden. When the Station at Svalöf took up its work, and indeed for many years after, there existed in the country a strong prejudice in favor of *Chevalier*, a prejudice which emenated from and was fostered by the brewers with great persistance as they were opposed to dealing with many sorts. Experience soon showed, however, that this sort was only suitable for soils which were tolerably fertile, deep, warm and not too stiff. On thinner, colder and moister soils, not only does *Chevalier* lodge badly but it produces a poorly developed and uneven product. This fact at once clearly indicated the necessity for systematic work, aiming at the production of sorts which would thrive to better advantage under various conditions and at the same time give a product which would in each case meet the requirements of the brewer. In response to this need, implying as it does that a "universal" sort, suitable for all conditions is not to be expected, much work has been done at Svalöf with this crop, which has resulted in producing several sorts which seem specially adapted to certain conditions, thus:—

Different sorts for different conditions.

Hannchen, for comparatively light soils.

Princess, for somewhat stronger so-called "good barley soils" such as that found in Central Skåne.

Primus, an Erectum type, for heavy humus and rich clay soils where the sorts belonging to the Nutans group are too weak in the straw.

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* This sort is known in England under the name *Archer*.

Chevalier II, for warm, fertile humus soils.

Swan-neck, for rich vegetable soils where specially early stiff-strawed sorts are required.

While the truth of the old saying "the right sort in the right place" is fully admitted and while the need for different sorts is recognized, yet the importance of restricting the number of sorts grown in *a given district* to as few as possible is likewise conceded.

For many years it was believed that the qualities which characterized a good brewing barley were largely external. Thus a sort with large, plump, uniform, well developed kernels of even maturity and possessing a smooth fine scale was always insisted upon, the degree of mealiness being the only *inner character* considered. Later, this standard of valuation became altered through the researches of various investigators who showed that the composition and therefore the true value of a sort cannot be accurately indicated by morphological characters. According to Haase of Breslau, a sort should not possess more than 11% protein when intended for brewing purposes.

In order to ascertain to what extent one sort might be better than another in regard to brewing qualities, a careful compilation was made by Tedin of analyses made at Alnarp of many different sorts which had previously been exhibited at the General Swedish Malting Barley Expositions held at Malmö from 1899 to 1904. These sorts represented therefore not only the product of different years but that of different localities. A study of these results revealed the interesting fact that in so far as protein content was concerned, the *Chevalier* variety enjoyed no advantage over other sorts which, up to that time, had not been popular with the brewers. The important conclusion regarding this whole question was therefore made that "*protein content, while probably a sort character, is one of subordinate importance in view of the enormous influence of such factors as soil, fertilizers, climate, weather conditions, kernel development, etc.*" (69, p. 183). This conclusion has also been reached in Denmark and Germany, after many years' careful work. In the light of the above observations an ideal brewing barley has come to be regarded as a *pure sort having plump, perfectly developed and matured kernels, which are rich in starch, clear in color, fine scaled and high in weight.* A sort which can comply with these conditions, no matter what its name may be, or what reputation it has enjoyed elsewhere, must be the aim of the breeder and should be encouraged by the brewer, since the two interests cannot be estranged.

An ideal brewing barley.

The difficulty of handling more than one or two sorts at the brewery moreover, is not considered a serious matter, in view of the comparative ease with which barley sorts may be identified and thus kept separate. This assertion of course, assumes the existence of only pure sorts, a matter which in the brewing industry perhaps more than in any other case, is of great importance. Not only are such sorts usually capable of quick identification but they possess in a high degree that first essential, viz., *uniformity of product* which alone can give an even germination in malting.

The identification and control of barley sorts is greatly aided by the system of classification commonly used in Scandinavia. This system is based on certain botanical marks on the kernel, on which basis all sorts commonly grown are grouped into distinct types. Its foundation was laid by Dr. Atterberg of Kalmar and subsequently improved upon by Neergaard although it remained with Bolin, who came later, to perfect the system which is in vogue to-day. This classification is as follows:—

Fig. XXXVI.—Classification of Barley Types.

Hordeum distichum nutans. Two-rowed barley; all kernels broadest in the middle and symmetrical in contour. Dorsal side of base of kernel with a slight horse-shoe-like excavation or depression.	Type I	(*α*) Kernels with long haired rachillæ (basal bristle) and lodicules and without teeth on the lateral nerves.
	" II	(β) Kernels with long haired rachillæ and lodicules and *with* teeth on the lateral nerves.
	" III	(γ) Kernels with short haired more or less woolly rachillæ and lodicules and without teeth on the lateral nerves.
	" IV	(δ) Kernels with short haired more or less woolly rachillæ and lodicules and *with* teeth on the lateral nerves.
Hordeum distichum erectum. Two-rowed barley; all kernels broadest in the middle and symmetrical in contour. Dorsal side of base of kernel *not excavated but often pinched with a transverse crease or furrow.*	Type V	(α) Kernels with long haired rachillæ and lodicules and without teeth on the lateral nerves.
	" VI	(β) Kernels with long haired rachillæ and lodicules and *with* teeth on the lateral nerves.
	" VII	(γ) Kernels with short haired more or less woolly rachillæ and lodicules and without teeth on the lateral nerves.
	" VIII	(δ) Kernels with short haired more or less woolly rachillæ and lodicules and *with* teeth on the lateral nerves.

Hordeum tetrastichum pallidum.

Ordinary six-rowed barley. All kernels from outer rows of the head slightly twisted; kernels from middle row symmetrical and distinguished from the two-rowed sorts by being broader nearer the tip, the base half being somewhat elongated.

Type IX (α) Kernels with long haired rachillæ and lodicules and without teeth on the lateral nerves.

" X (β) Kernels with long haired rachillæ and lodicules and *with* teeth on the lateral nerves.

" XI (γ) Kernels with short haired more or less woolly rachillæ and lodicules and without teeth on the lateral nerves.

" XII (δ) Kernels with short haired more or less woolly rachillæ and lodicules and *with* teeth on the lateral nerves.

Note.—The different barley types are commonly distinguished in Scandinavia by Greek letters. (See in brackets above.)

The constancy of the peculiar character of rachillæ or basal bristle of the different sorts is remarkable. The development of teeth on the lateral nerves on the other hand is not quite so constant a character. Thus in types II and IV, for example, the development of teeth on certain kernels belonging to a given sort may not always be well pronounced. In the same manner, sorts belonging to Types I and III may produce kernels on the nerves of which an occasional well developed tooth is to be found. Despite these occasional irregularities the presence or absence of these teeth is regarded as of great importance as a distinguishing feature.

Concerning the various botanical marks under consideration, the question has been raised as to whether or not all kernels on the same plant invariably possess the same peculiar character of rachillæ. A German writer (Broili) expresses the opinion that although variations of this sort may not occur in Sweden there is no reason why they should not arise in other countries. Regarding this question Tedin (73, p. 5) says: "There is nothing to show that the soil and climate of Germany should be more capable of producing variations of such a nature than is that of Sweden." Discussing the possibility of these variations arising even at home, he says: "I have worked for eight years with barley and with hundreds of pure lines but have never yet found a single example of such variation.". While strictly speaking, the above system must be regarded as a means of distinguishing *types* rather than sorts, yet it will readily be seen that the genuineness of a given sort may often be determined on this basis. An instance may here be given: At present there are only two pure sorts belonging to Type I on the Swedish market. These are *Princess* and *Hannchen* which bear the stock book numbers *0105* and *0110* respectively. Should a quantity of barley be offered for sale or placed on exhibition under the name of either of these sorts it would be an easy matter to decide whether or not the goods really

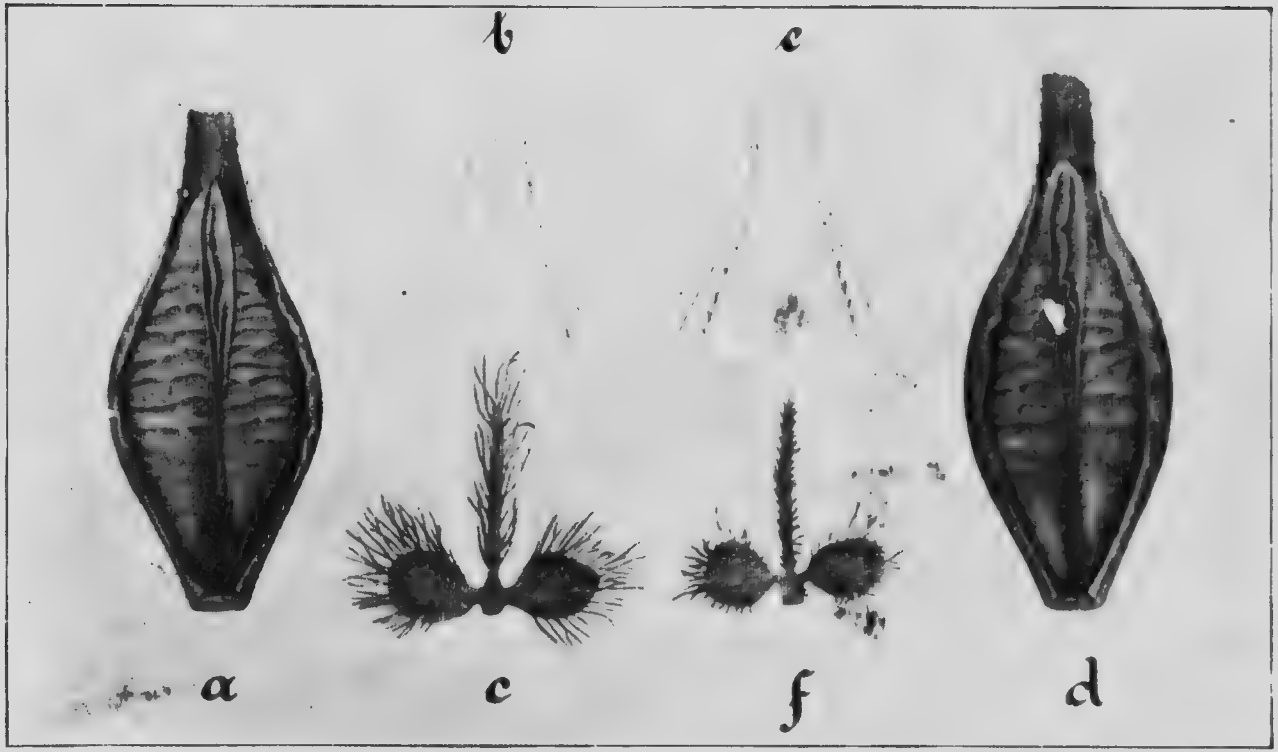

Illustration by courtesy S. S. Ass'n

Fig. XXXVII. Distinguishing characters in barley kernels: a and c long-haired rachillæ and lodicules; *d* and *f* short haired more or less wooly, rachillæ; *b* lateral nerve without teeth, *e* ,with teeth.

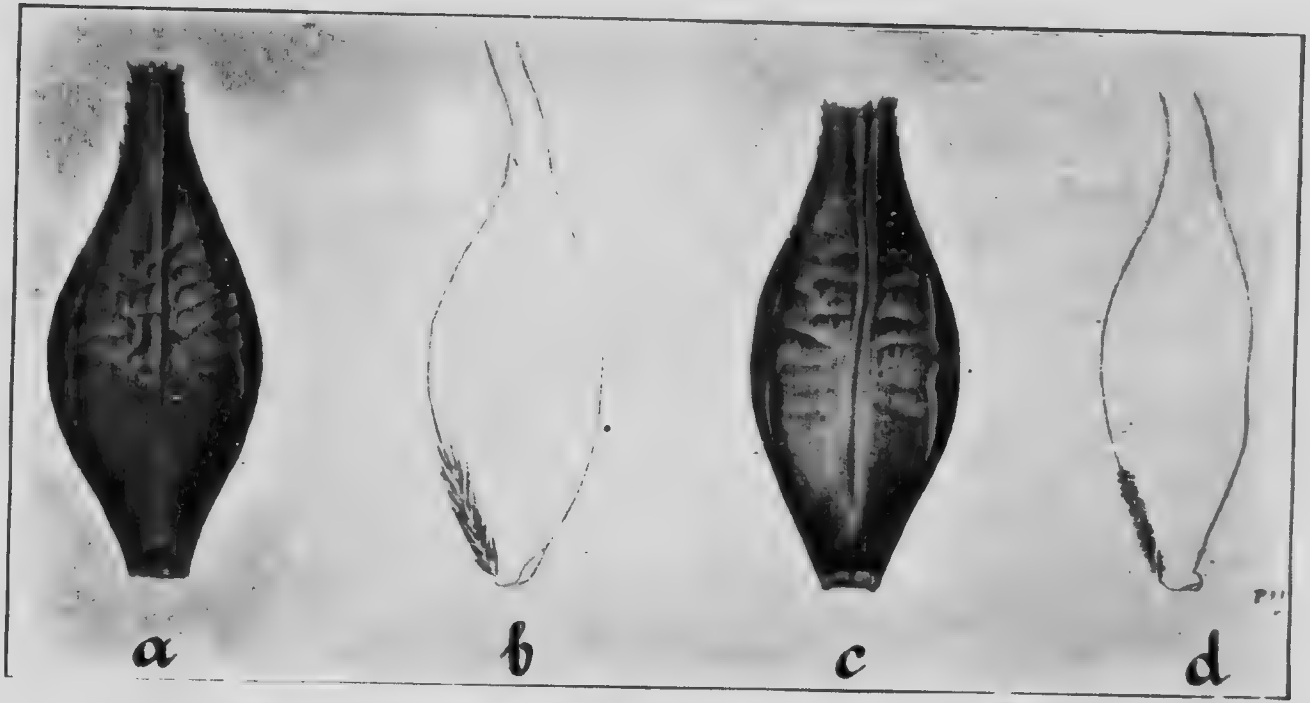

Illustration by courtesy S. S. Ass'n.

Fig. XXXVII.—Distinguishing characters in Barley kernels: *a*, and *b*, showing characteristic form of base in Nutans group; *c*, and *d*, showing base peculiar to Erectum group.

belong to Type I. This fact makes it possible to prevent much abuse, such as the distribution of old mixed varieties under the names of sorts which are more popular and of greater value. To distinguish *Princess* and *Hannchen* from each other is another matter. Fortunately the shape of the kernel of these sorts is sufficiently different to enable a distinction to be made between them when bulk samples of each rather than single kernels are examined. Similar differences often exist between sorts which are classified under the one group.

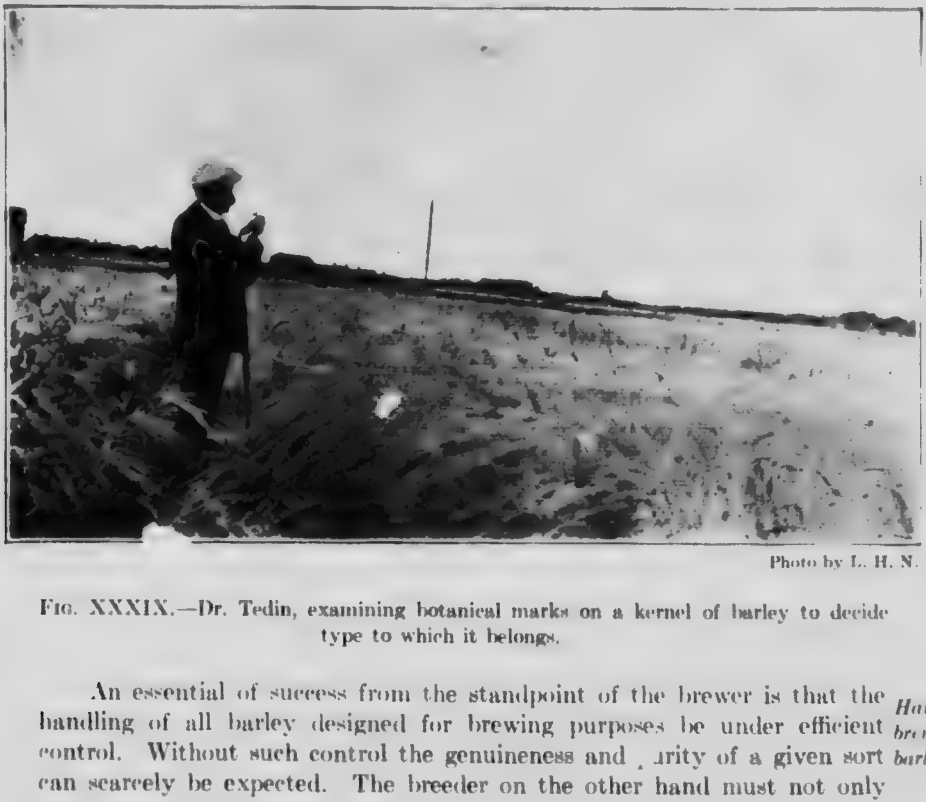

Photo by L. H. N.

FIG. XXXIX.—Dr. Tedin, examining botanical marks on a kernel of barley to decide type to which it belongs.

Handling of brewing barley.

An essential of success from the standpoint of the brewer is that the handling of all barley designed for brewing purposes be under efficient control. Without such control the genuineness and purity of a given sort can scarcely be expected. The breeder on the other hand must not only seek to produce still better sorts but he also must see that these are distributed with every possible precaution.

The points considered in judging brewing barley are as follow:—

Points considered in judging brewing barley.

(1) Purity of the sort. (2) Freedom from other kinds of grain. (3) Uniformity of product. (4) Character of scale. (5) Shape of kernel. (6) Color of kernel. (7) Mealiness. (8) Nitrogen content. (9) Size of kernel. (10) Growing power. (11) Damaged kernels. (12) Odour.

The degree of *mealiness* is commonly judged by the color—from quite starchy to glossy or flinty—when the kernel is cut crosswise through the centre. It has long been believed that the more mealy or starchy the kernel, the lower the per cent protein. While experience seems to have given some support to this belief, yet careful investigation shows that the relationship existing between the per cent protein and degree of mealiness is not so intimate as many have thought. This is quite clearly shown by Tedin in the following table (68, p. 229):—

Year	Average Protein Content %	Average Mealiness %
1900	10·98	27·8
1901	9·62	64·4
1902	9·53	54·4
1903	9·55	50·4
1904	9·35	61·0

Investigations seem to indicate further that the degree of mealiness or starchiness is dependent to a certain extent upon weather conditions. Thus a flinty kernel under certain conditions of moisture either before or after harvest can be changed to one which appears quite starchy. For this reason it is claimed that the degree of mealiness if taken into account at all, should be noted only after the kernel has been soaked in water.

The measure of quality in barley.

The measure of quality in the barley kernel most commonly used is the *absolute weight* (weight per 1,000 kernels) and the *volume weight* (weight per hectolitre). The absolute weight is important in judging different lots of the same sort, but signifies little in judging different sorts, as a large kernelled sort, and therefore a heavier sort per 1,000 kernels, need not necessarily be of more value or of even better quality than a smaller grained sort. What might give the larger kernelled sort greater value is the smaller per cent scale and the correspondingly larger per cent kernel. In this case fewer kernels are required to give the same weight. The shape of kernel can also influence quality in that those which are thicker and shorter have more kernel in proportion to scale than have those which are longer and thinner. It is important in any case that no sort falls below a certain standard. Little variation in weight per 1,000 kernels in the same sort from year to year is regarded as suggestive of the power of the sort to adapt itself to different conditions as it is well known that different conditions of season exert an important influence on weight.

Interesting data have been compiled by Tedin (70) showing the weight per 1,000 kernels of different sorts for different years at Svalöf and at Ultuna. An examination of the table comparing the average weights per 1,000 kernels of the different sorts at these places shows that without exception, this weight is greater at the Northern Station than in the South

The *weight per bushel* is not considered so important as is the weight per 1,000 kernels as this weight depends largely upon the shape of the kernel and on the severity of the threshing. Thus, as in oats and other grains, the shorter and thicker the kernels the more closely they may be packed in a given measure and consequently the higher the weight per bushel. Severe threshing produces a shorter, blunter kernel and is often resorted to as a means of increasing the weight per bushel of a mediocre ware. The objections to such a practice are clearly pointed out in that not only is the apparent value of sorts so treated exaggerated, but at the same time there is great danger of injuring the germs of the kernel and thus reducing the germinating power. The weight per bushel of the leading two-rowed sorts at Svalof is given later in connection with the table of yields.

The *time of development* is an important consideration in barley culture in Sweden as even in the most southern parts the grower desires as early a sort as possible so long as earliness be not obtained at the sacrifice of yield or other practical qualities.

Photo by L. H. N.

FIG. XL.—Dr. Tedin taking final notes re date of ripening, etc., on large comparative trial plots of barley (Aug. 9, 1910).

Of the large number of two-rowed strains isolated and tested during the nineties, the following are the most important:—

Princess out of the old English Prentice; *Chevalier II* out of American Chevalier; *Gute* out of a native barley peculiar to the Island of Gotland; *Primus* and *Swan-Neck* selected from a mixed stock said to have been the product of a crossing between Imperial and a common two-rowed sort; *Hannchen* out of the Austrian sort known as *Hanna*.

Since the greater number of forms tested during the above period had been duly eliminated, new and extensive collections were again made in 1900 and the succeeding years, but this time greatest attention was given to the common native sorts. Although the new and tried sorts mentioned, had obtained a fairly wide distribution yet by reason of the fact that the most of these came from foreign sorts, many farmers still clung with considerable prejudice to the old native varieties. The special attention given these latter varieties at Svalöf was therefore inspired very largely by a desire to cater, as far as possible, to these prejudices. The material for this new work was obtained chiefly from samples exhibited at Malmö at the large barley exhibitions held annually at that place from 1899 to 1904, although a number were also obtained from local seed fairs and from interested farmers.

Photo by L. H. N.

FIG. XLI.—Dr. Tedin collecting types of barley for photographing.

These samples naturally came from different places in the country and were all more or less mixed. From the progeny of these different lots together with others worked with later, there were isolated hundreds of different strains from which not less than 34 came into the large comparative trials at Svalöf. Of this number there remained in 1910 twenty-one, of which 16 came from old native varieties and 5 from the mixed *Chevalier*. In 1909 one of these sorts (0214) from *Chevalier* gave the highest yield of grain of all sorts tested, while on the average of the four years 1906-1909, two sorts, *0125* out of a native variety and *0412* out of a common mixed Chevalier, gave the highest yield of all sorts tested during that time with the exception of *Gold* (0202) which proved somewhat more productive.

In addition to the native material, about 200 forms were taken from stocks brought from other countries. These came largely from France, England and from high altitudes in Switzerland. Certain of the Swiss sorts proved exceedingly early, but on account of imperfect development of kernels, only one sort (0160) has been able to qualify for further testing in the large trial plots.

Of the French material only one sort (0166) has succeeded in winning a place in these large trials, while none of the later English importations have qualified for this position.

Six-rowed barley.

Many six-rowed varieties of barley have been obtained from different districts in Sweden as well as from other countries such as America, Denmark, Norway and Siberia. Contrary to expectations, forms from the province of Dalarne and even from that of Skåne were found to be quite as early as were those from the most northern regions. This fact served to prove not only that earliness is an hereditary character, but that strains suitable for the north might be found in composite varieties grown in the south, although they must be tested in the districts for which they are intended. The absence of adequate trial grounds in these northern districts has delayed progress with this crop, so that the results to date are of no special significance.

Leading two-rowed barley sorts.

The leading two-rowed barley sorts either now in circulation in Sweden or about to be distributed are described below in the order of their importance.

Gold Barley (0202), a pedigree sort taken from the native so-called Gotland barley in 1896, has given the highest average yield of grain of all sorts tested both at Svalöf and at Ultuna, for the years 1900-1909. As the stock-book number indicates this sort belongs to the Nutans group, Type II. The kernels are short and thick resembling somewhat those of *Chevalier*. The straw is relatively low and fine though strong; ripens about the same time as Hannchen; kernels inclined to sprout very readily after harvest.

Princess (0105) is a pedigree sort out of Prentice. This sort is rather later than *Chevalier*, and is generally regarded as more suitable for the southern parts of the country. The kernels are of fine quality and of about the same weight per 1000 as those of *Chevalier*, but the weight per bushel is somewhat lower. Is most suitable for good, deep but not too rich soil, but not at all for poor soils or such as suffer specially from dry weather. Ripens the latest of all two-rowed sorts commonly cultivated. Sprouting after harvest, medium.

Hannchen (0110) is a pedigree sort taken from a variety known as Hanna imported from the famous barley district of the same name in Mähren, Austria. Popular chiefly on account of its earliness, good strength of straw, and relatively high yield of grain. Kernels rather long with particularly fine testa. Weight per 1000 kernels somewhat lower than with Chevalier, but weight per bushel, on the other hand, a little higher. On account of relatively small straw and sparse leaf development it can withstand drier weather and lighter soils than most sorts.

"In experiments conducted by 'Die Gerstenkultur Station des Vereins Versuchs und Lehranstalt für Brauerei' (the barley culture station of the Association's Experimental Institution and Brewery school) in Berlin in

1904-1905, Hannchen, particularly on lighter soils and in many cases even on better barley soil, showed itself to be the most productive and best brewing sort" (70, p. 54). In Sweden this sort thrives best on a warm, limestone soil. On stiff clays or on rich vegetable soils, experience has shown it to be uncertain. By reason of its earliness it can be grown relatively far north, providing the soil be suitable. It has been found relatively susceptible to attacks of the loose smut (*Ustilago nuda* Jens.) Sprouts very little directly after harvest.

Primus (0706), as the number indicates, belongs to quite another type than the three foregoing sorts. This sort was selected out of Diamond, which is said to have been an unfixed product of a crossing between a nutans form, probably *Chevalier*, and *Imperial*. Kernels are well formed, fine scaled and usually possess an especially attractive light color. Straw long and arched but strong. Ripens a little later than *Hannchen* and *Gold*. Is suitable for humus and rich clay soils where the nutans sorts are likely to be too weak. On the heavy cold soil at Svalöf it has given about the same yield as *Hannchen* and *Princess*. Sprouts after harvest about the same as Hannchen.

Chevalier II (0403) is a pedigree sort taken from Horsford's crossbred Chevalier of the United States of America. Has rather a plumper kernel than the common Chevalier and yields a little better. On warm, fertile humus soils it gives very good satisfaction. The original variety as obtained from the United States was not pure, although type IV predominated. Ripens between *Princess* and *Primus*. Sprouts after harvest about the same as Princess.

Swan Neck (0506) is a sister sort of *Primus*. This is the earliest of all two-rowed pedigree sorts cultivated in Sweden and is particularly suited to rich vegetable soils where early, stiff strawed sorts are specially desired. The head is bowed or arching, hence the name "Swan Neck." The kernel is quite well formed with good weight. Grows after harvest about same as *Gold*. The pedigree of *Swan Neck* and *Primus* is given below as follows:—

A common two-rowed sort
(probably *Chevalier*)
×
Imperial
} *Diamond*
/ *Swan Neck*, 0506
\ *Primus*, 0706

The above is an interesting example of the possibilities of obtaining distinct types suitable for different soils and different purposes from the same crossing.

Fig. XLII.—Table of yields of leading Two-Rowed Barley sorts at Svalöf from 1894 to 1910.

Names and Stock-book number of sorts.	No. of years tested.	Average yield in pounds per acre.		Yields compared with Chevalier II.		Average weight per Bus.	Average weight per 1000 Kernels
		Grain	Straw	Grain %	Straw %	Lbs.	Grams.
0202, Gold barley (Pedigree out of Gotland)...	11	3093	3133	110·6	89·7	53·8	41·6
0105, Princess barley. (Pedigree from Prentice)	17	2984	3612	106·7	103·4	52·6	42·27
0708, Primus barley (Artificial crossing product).................	14	2925	3401	104·6	97·3	35·7	48·71
0110, Hannchen barley (Pedigree out of Hanna from Austria)..........	14	2916	3056	104·3	87·5	53·0	41·75
04 3, Chevalier II (Pedigree sort)..............	17	2796	3495	100·0	100·0	53·5	44·50
— Common Chevalier..	9	2686	3534	96·1	101·1	52·6	42·98
0506, Swan Neck. (Artificial crossing product).	15	2647	3208	94·7	91·8	52·0	48·32

In 1910 there were 30 different sorts in the large comparative trial plots at Svalöf, each sort occupying 3 different plots. Of stock multiplications intended for immediate delivery to the Swedish Seed Company there were five, while of ordinary sort multiplications intended for further testing in special experiments, etc., there were seventeen. Of small *pedigree cultures* there were about two hundred and seventy. Approximately seventy of these consisted partly of the same sorts as were in the large comparative trials and partly of other pedigrees still in the preliminary stages. The remainder were as follow:—

Two-rowed sorts, including pedigree plots, in experimental grounds in 1910.

170–284	Consisting of a series of pedigrees in the second generation, the mother plants of which had been taken without regard to morphological characters, from a common country sort grown at "Ellinge" Farm near Eslöf, Skåne.

303–307 = *Princess* × *Chevalier*—2nd generation.

Object.—To obtain a sort combining the high yield of *Princess* with the qualities in which *Chevalier* excels. Although both sorts are rather weak in the straw, it is believed possible to obtain a sort possessing greater strength than either parent. The characters concerned in this crossing may be illustrated more clearly in the following manner:—

Princess.	*Chevalier.*
(a) Low weight per bushel due to loose attachment of scale.	(a) High weight per bushel.
(b) Rather late in ripening.	(b) Earlier in ripening.
(c) Head often remains partly in the sheath. This is an objection, since under unfavorable conditions such as continued drought or when sown on stiff clay soil, considerable damage is likely to result both to quality as well as to quantity. Should the harvest be wet it is also more difficult to dry out the grain when enclosed in a sheath.	(c) Head shoots well out of the sheath.
(d) Rather weak in the straw.	(d) Rather weak in the straw.

308–310 = *Princess* × *0156* (a very early strain)—2nd generation.

Object.—To combine the higher yield of the former with the earlier ripening, stiffer straw and better shooting of the head of the latter.

311–314 = *Hannchen* × *0156*—2nd generation.

Object.—To obtain a still earlier sort than *Hannchen*, but retaining the good quality of the latter.

315–316 = *0156* × *Hannchen*—2nd generation. (Reciprocal crossing.)

317 = *Hannchen* × *Gold*—2nd generation.

Object.—To obtain a sort combining the higher yield, greater resistance to loose smut and power to germinate more quickly after harvest of *Gold* with the power to grow over a greater variety of soils possessed by *Hannchen*. The very slow germination of *Hannchen* after harvest is not liked by the brewers.

318-320 = *Gold* × *Hannchen*—2nd generation. (Reciprocal crossing). The characters or qualities specially concerned in this crossing are as follow:—

Hannchen.	*Gold.*
(a) Among the highest yielders.	(a) Highest yielder.
(b) Especially susceptible to loose smut.	(b) Not specially susceptible to loose smut.
(c) Sprouts very slowly on exposure during or after harvest.	(c) Sprouts very quickly on exposure during or after harvest.
(d) Able to thrive on relatively light and dry soils	(d) Able to thrive on a great variety of soils, although probably not so great a number as with *Hannchen.*

321–322 = *0156* × *Gold*—2nd generation.

323–325 = *Gold* × *0156*—2nd generation.

326–328 = *Chevalier* × *Gold*—2nd generation.

329 = *Primus* × *Princess*—2nd generation.

Object.—To obtain a sort combining the high yield and quality of the latter with the stiffness of straw, earliness of maturity and ability of head to shoot well out of the sheath possessed by *Primus.*

330–333 = *Primus* × *Chevalier II*—2nd generation.

Object.—To obtain a sort combining the stiffer straw, earlier maturity and higher yield of *Primus* with the better quality of the latter sort.

335–341 = Old mixed sorts sown with a view to providing material for pedigree selection.

The present status of barley breeding work at Svalöf when compared with that of twenty years ago, affords undisputed evidence as to the progress which has been made with this crop since the inception of the work. The table of yields, while illuminating, does not tell the whole story. While the production of sorts capable of producing higher yields than those formerly grown is immensely important, yet the availability of sorts specially suited to certain conditions is of no less value. Thanks to the skill of the Svalöf experts the farmers of Sweden are now able to obtain sorts which are better suited to their respective conditions than were those available in the old days. With the excellent material now available in the way of pure and thoroughly tested sorts much is expected of artificial crossing, a phase of the work which with barley as with the other cereals, is being prosecuted with energy.

5. The Breeding of Pease*

Pease are grown in Sweden chiefly as a fodder crop in conjunction with oats and vetches, where they form a most valued ingredient. As a grain crop they occupy a relatively unimportant place, less than 1% of the whole cultivated area being devoted to their production for this purpose. This is due to a variety of causes, but chiefly to the frequent occurrence of conditions which promote continued growth of foliage at the expense of seed production. Despite these difficulties the value of the pea crop, both as a fodder and as a grain crop, has always been regarded sufficiently great at Svalöf to warrant the best efforts of the breeder in attempting to produce more suitable sorts. The difference between sorts in regard to various practical qualities, and their varying attitudes towards different conditions of soil and climate, rendered it necessary first of all to collect and test in large trial plots a number of the best Swedish as well as foreign sorts. The close examination and study to which this collection was subjected soon revealed the nature and extent of the deficiencies in the then available material and showed that improvement, in the form of more *suitable* sorts, was absolutely imperative if the growing of pease was ever to become even a partial success. The old varieties were more or less uneven and usually very uncertain in ripening. Under favorable conditions a very good crop might often be realized, but when conditions were the reverse, and this unfortunately is too often the case in Sweden, an almost absolute failure might result. If, for example, the harvest be cool and moist the plant may continue to grow and bloom until insufficient time remains for the seed to ripen. In this case not only is the grain sacrificed but the quality of the straw likewise suffers in that the lower portions become leafless and not infrequently become badly decayed. Under these circumstances one of the most pressing needs, especially when breeding for grain, is for a sort which will mature with certainty each year even under relatively adverse conditions. In working toward this end Tedin has found that certain sorts or *pure lines* which bloom about the same time may behave differently under certain conditions, some sorts being less sensitive to excessive rainfall than others. *The Concordia* variety for example, begins to bloom about the same time as does another sort out of the *Östgöta* variety, but when the precipitation is abundant, the latter may continue to grow and bloom indefinitely, while the former ripens almost normally.

Among the old varieties all was confusion and uncertainty regarding names and practical values when the work at Svalöf began. One could obtain, for example, samples under the name of *Östgöta Pease* from different sources but which on being grown revealed enormous differences. Indeed, the records show that these lots often resembled each other so little that between the earliest and the latest there might be a difference of from three weeks to a month in ripening.

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* Some very interesting work has been done by Tedin with Vetches as well as with Pease, but since the former crop does not occupy a large place in the Agriculture of Canada and since the principles of improvement as well as the methods of handling are practically the same in both cases, it will not be discussed in this paper.

Not only were great differences discovered between different lots of the same old varieties but *within each lot* was often to be found a "motley collection of quite distinct types." When the pedigree method came to be applied to this crop, as it did about the year 1892, it quickly served to isolate a large number of these types, which, on further investigation, were found to possess qualities of varying practical values. Much work from that time on was devoted to the isolation of distinct strains which would be suitable for growing under different conditions of soil and climate and which would possess constant and well defined botanical characters. As the work proceeded it was found that the morphological differences which characterize many strains, while often small, are usually quite constant. This, as in the cereals, is a matter of great importance as it not only provides a means of keeping under control those sorts which have been placed on the market, but at the same time affords protection against misrepresentation and fraud in the ordinary course of business.

Photo by L. H. N.

FIG. XLIII.—Dr. Tedin crossing Pease.

While experience showed it to be possible to separate out a large number of different strains from the common varieties by means of the pedigree method, yet it was not long before other methods came to be included. Thus artificial hybridization was introduced on an extensive scale and as we shall see later, occupies a prominent place in the improvement of this crop. Unfortunately many promising crosses have had to be laid aside owing to the absence of proper facilities for testing at different local centres.

The difference between Pea sorts as regards such matters as *earliness* is considerably greater than in the case of cereals, while the influence of soil and climate is also greater in the former crops than in the latter. For this reason local trails are absolutely imperative and where inadequate provision is made for such trials it is considered only a waste of time, energy and material to attempt to obtain reliable data as to the real standing of different sorts. That such trials have not thus far been made on a larger scale in Sweden has been due to the cost of operating such, and to the relatively unimportant place which this crop occupies in the country as a whole. Wherever trials have been conducted it has been possible to include only a few sorts so that many promising crossing products have had to give way to the older sorts which are still under investigation and which necessarily demand considerable space and attention.

System of classification.

Of the cultivated Field Pease two species are commonly distinguished, viz., *Pisum Sativum* L. which produces white flowers, and *Pisum Arvense* L., having red flowers. Within each of these species many different types and varieties have been distinguished and described. In order to facilitate the handling of large numbers of individuals belonging to different types Tedin has devised a system of classification by which the different types are arranged in groups according to the color of the flowers, stipules, leaf axils and seeds as well as the shape of the seeds. In order to make this grouping more suggestive, a Latin affix referring usually to the color of the seed has been added to the Latin name in each case. This classification is given below as follows:—

Group I.—*Pisum Sativum commune*, H. Tedin. Flowers white. Leaf axils green, unpigmented. Seed usually round or almost round with a smooth or only occasionally wrinkled scale; in color yellow-white.

Group II.—*Pisum Sativum glaucospermum*, Alef. (Glaucospermum indicating blueish-green seeds). Flowers white and leaf axils green as in the foregoing. Seeds also resembling the former in shape but in color green-blue, green.

Group III.—*Pisum Arvense unicolor*, H. Tedin. Flowers colored, or pigmented; standard from very light to a darker red, usually with a more less obvious shifting to violet; wings relatively dark colored, violet-red to deep blue-purple. Leaf axils dark brownish purple or red-brownish. Seeds one-colored (unspotted), gray-green or gray-yellow.

Group IV.—*Pisum Arvense punctatum*, H. Tedin. (Punctatum signifying in this case "dotted" or spotted seeds). Flowers and leaf axils the same color as in Group III. Seed covered with purple or blueish dots or spots.

Group V.—*Pisum Arvense maculatum*, H. Tedin. Maculatum indicating here a speckled or marbled color of seeds). Flowers and leaf axis as in Group III. Seeds spotted or marbled with rust-red to brownish spots.

Group VI.—*Pisum Arvense punctato-maculatum*, H. Tedin. Flowers and leaf axils as in Group III. Seeds covered both as in Group IV (Punctatum) and as in Group V (Maculatum).

Group VII.—*Pisum Arvense immaculatum*, H. Tedin. (Immaculatum meaning uncolored or "unspotted.") Flowers light; standard almost white; wings pure light-red (rose-red) or very light purple or aniline-red. Leaf axils essentially the same color as in Group III although in the main lighter. Seeds unspotted.

Group VIII.—*Pisum Arvense atomarium*, H. Tedin. (Atomarium signifying in this case that the seed is covered with very fine dots). Flowers and leaf axils as in Group VII. Seeds with sparse, light to dark purple-colored dots or small spots.

Group IX.—*Pisum Arvense maculosum*, H. Tedin. (Maculosum meaning speckled or marbled as in Group V.) Flowers and leaf axils as in Group VII. Seeds with rust colored spots or marbelling as in the case of *maculatum* (Group V.).

The leading sorts of pease at Svalöf at present are as follows:—*Gröp* (0305), *Solo* (0401). *Concordia* (0234), *Capital* (0137) and *Capital II* (0185). The yields of these together with others of less value are given in the following table:—

Fig. XLIV.—Table of yields of Pease at Svalöf 1893-1909 (22 p. 30).

Names and Stock-book number of the sorts.	No. of years tested	Yield per acre. (Average)		Yields compared with *Capital* pea.	
		Grain (lbs.)	Straw (lbs.)	Grain %	Straw %
0305, Gröp (grinding) pea. (Pedigree out of *Early Britain*)......................	10	2459	2456	112·4	87·0
0401, Solo pea. (Pedigree out of *Early Britain*)............................	10	2397	3033	105·0	107·4
0234, Concordia. (Pedigree out of the *Blue-Green* English variety)............	10	2281	2860	104·3	101·3
0137, Capital. (Pedigree out of a German variety)............................	17	2188	2823	100·0	100·0
0185, Capital II. (Pedigree out of a German variety)........................	10	1962	2750	89·7	97·4
— Victoria pea. (An English variety).	7	1713	3345	80·2	118·5
— Östgöta pea. (Variety commonly grown in middle Sweden)............	7	1576	3274	72·0	116·0
— Peluschker pea....................	12	1297	3126	59·3	110·7
— Yellow Skåne pea. (Variety commonly grown in the Province of Skåne) ..	5	1175	3032	53·7	107·4

Photo by courtesy S. S. Ass'n.

FIG. XLV.—Svalöf's Solo Pease.

Description of leading sort.

0305, Svalöf's "Gröp" or Grinding Pea, is a pedigree sort out of the English sort *Early Britain* and is at present the leading sort for grinding purposes. On account of the meagre development of its foliage it is not suitable as a soiling crop. Came on the market first in 1907.

0401, Solo Pea, is a sister sort of the above but unlike the latter is especially valued as a sort for soiling purposes. It is about eight days later in maturing and produces large brownish seeds, which frequently are covered with fine blueish dots. In the field it is easily distinguished from all other Arvense sorts in that the axils are colorless or a light green as in the white flowered sorts although the flowers of this variety are normally pigmented (red or violet). This sort was first placed on the market in the spring of 1906.

0234, Concordia Pea, is a pedigree sort out of the old *Blue-Green English* variety and is the highest yielding cooking pea yet produced at Svalöf. The straw is short. The seeds are quite large, somewhat flattened and blueish-green in color. Since green colored cooking pease are not popular in Sweden this sort has been crossed with such sorts as *0157* and *Capital II* which possess a more desirable color, namely pure yellow. Came on the market for the first time in 1906.

0137, Svalöf's Capital Pea, is an especially fine tasting cooking sort, and produces a good yield under suitable conditions. The seeds are average size, yellow or often somewhat greenish in color. Came on the market in 1904.

0187, Svalöf's Capital II, resembles *Capital* closely in date of maturity and yielding power, but differs from it in certain botanical characters. The pods are usually somewhat smaller and frequently occur two together on the one pedicle. The seeds are commonly of a deeper yellow than is usually the case in the last mentioned sort. Came on the market first in 1907.

The *Victoria* Pea, which is believed to have originated in England, was introduced into Sweden from Germany in the eighties, and quickly obtained a very wide distribution. It is a tall growing, coarse stalked sort producing large, round, yellow seed. Owing to its disposition to continue growing past the normal time of maturing, especially during moist seasons, it has had to take a minor place in competition with the earlier maturing productions.

The above six sorts with the exception of *Victoria,* were under investigation in the large comparative yielding tests in 1910. In addition to these sorts twelve others of varying practical values occupied a similar position. These were as follows:—*Ösgöta yellow*; *Östgöta yellow* from Braberg; *Early market; 0115*, a pedigree sort out of *Early Blossom; 0152*, a pedigree out of a German variety; *0159*, out of a yellow variety grown in the district of Örebro; *0351* out of a Danish sort; *0550* the product of an artificial crossing between *Early Britain* and a Norwegian pea (*Early Sand*); *0632* and *0633*, pedigree sorts out of the Danish variety *Marmoreret Glæno; Marmoreret Glæno; Jemtlands Grey* and *Rättviks.*

Pedigree plots under investigation in 1920

In the section devoted to small pedigree cultures were to be found approximately 200, about one-half of which consisted of pedigrees taken out of old mixed varieties, while the other half consisted of the products of artificial crossings in different generations. Of the different series under consideration the following may be nemed, the field numbers being used in each case:—

87–91 Pedigrees out of a stock of Grey peas obtained from E. Berg, Gårdsjö, Rättvik.

95–106 — Pedigrees out of a stock of the so-called *Jemtland pea* obtained from Count Mörner, Birka, Tång.

107–115 — Products of artificial crossing between *Capital II* and *Concordia*—3rd generation.

The object of this cross is to obtain a sort combining the general type of plant and productiveness of *Concordia* with the more popular shape and color of seeds (round and pure yellow) of *Capital II*.

116–120 — Products of artificial crossing between *Solo* and *0351*—3rd generation.

121–133 — Products of artificial crossing between *Solo* and *Peluschken*,—3rd generation.

134–144 — Products of artificial crossing between *0351* and *Peluschken*—3rd generation.

The object of crossing the above three green-fodder sorts is to obtain if possible, still better sorts for this purpose, by a better combination of certain characters.

145–167 — Products of different crossings in the 2nd generation.

6. The Breeding of Clovers and Grasses*

Owing to financial limitations and to the more pressing need for active work with cereals during the early years of the Association's activities, systematic work in the improvement of grasses and clovers did not begin at Svalöf until about 1907. Since that time this branch of the Association's operations has been in charge of Dr. Hernfrid Witte.

Approximately 36% of the cultivated area of Sweden is devoted to the production of fodder crops of which grasses and clovers constitute by far the major part. The leading grasses are *Timothy, Orchard grass, Meadow fescue* and *Tall Oat grass*, while in clovers the *Early Red* and *Late Red* stand pre-eminent. Over twenty million pounds of grass and clover seed are required annually to sow the area devoted to these crops. Of this quantity about two-thirds is produced within the country, and this consists almost exclusively of Late Red clover, Timothy and Alsike. The remaining one-third of the seed is imported from such countries as Germany, France, Chili and America, all of which countries occupy a more southern position than that of Sweden. As a result of this difference in latitude, sorts produced from seed obtained from the countries indicated are invariably less hardy than the Swedish sorts which have become acclimatized and are now quite as hardy as are the wild strains.

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* The data on work with grasses and clovers which are submitted in this paper, have been obtained chiefly from publications, including annual reports, by Dr. Witte.

During the years 1907-1910 careful comparative trials were conducted at Svalöf with a large number of Swedish and foreign clover sorts. These trials showed that the Red Clover from the province of Silesia, Germany gave, after the favorable winter of 1907-8, almost as high a total yield as did the best Swedish clover. The winter of 1908-09, however, was more severe with the result that the Silesian clover yielded from 15 to 20% less than the Swedish, while the English and Chilian were completely killed out

Clovers.

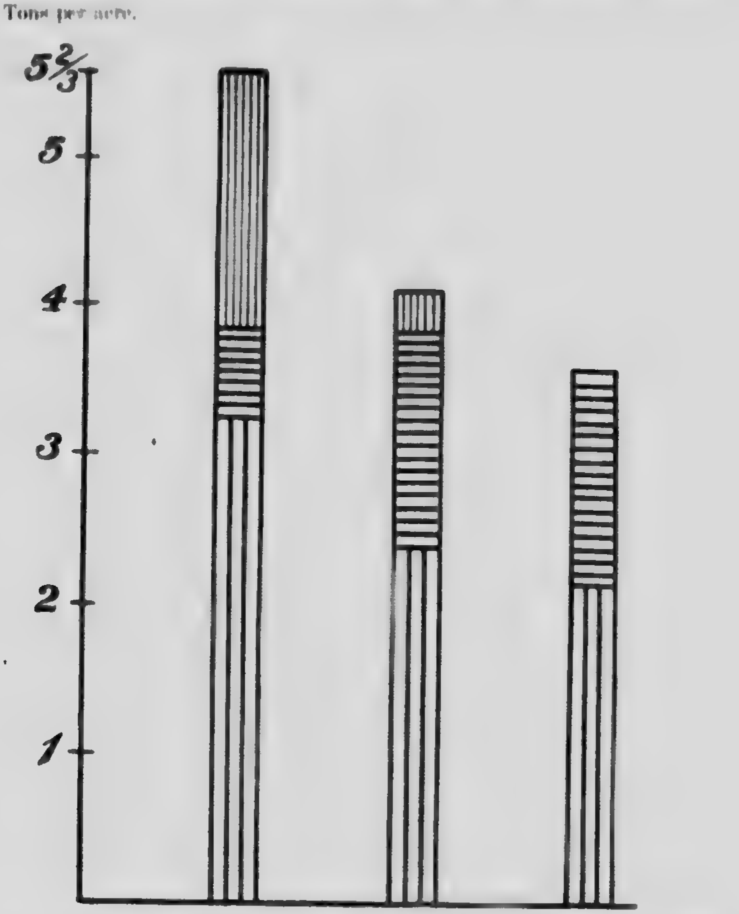

Fig. XLVI.—Comparison of Swedish and foreign Red Clover Sorts. The lower vertical lines indicate the first cutting of 1908, the horizontal lines the second cutting of 1908 and the upper vertical lines the crop of 1909. [Witte, H. Sveriges Utsädesförenings Tidskrift 910, p. 321.

Similar experiments at Vesterås, about 70 miles west of Stockholm, were still more in favor of the native sorts. These and other experiments have demonstrated that Silesian clover is the only foreign sort which may be imported into Sweden with safety, and this only in the southern provinces.

A matter of importance in clover is the production of second growth or "aftermath." The Swedish sorts are from two to three weeks later than the imported sorts and the aftermath is consequently considerably smaller. In *total crop*, however, the former sorts are found to excel the latter by a substantial margin. Because of their lateness the Swedish sorts are also more suitable for mixing with Timothy as they ripen at about the same time as that crop. The early sorts, on the other hand, are ripe before the Timothy is in best condition for cutting.

Late Red Clover may be distinguished from the early strains not only by time of ripening but by certain morphological characters. It is taller, more branching, greener in color with a smaller percentage of heads placed near the top of the plant. Late clover is also said to be longer lived than is the Early while on colder, poorer soils which are not too dry it is found to thrive better than the latter. The greater hardiness of Late Clover, as already mentioned, is perhaps its greatest virtue, although it has also shown itself able to resist certain diseases, notably clover-rot (*Sclerotinia Trifoliorum*, Erikss.) (36, p. 158).

A good deal of The Swedish clover has become mixed with the more delicate foreign sorts which have been introduced through the trade, and is consequently of inferior value. Witte (81, p. 319) has found for example, clovers of the early smooth (so-called Silesian) type and of the early hairy (so-called American) type among different strains of Late Swedish. Even among stocks which are regarded as being genuine Swedish, types have been distinguished which reveal distinct differences in regard to productive power and other practical qualities.

In view of the above circumstances the work of the Association at Svalöf with clovers has for its object the *production of hardy, uniform races of known origin and purity and of approved value for cultivation in the different parts of the country*. Sorts which bloom about the same time and which are otherwise suitable for growing together in mixtures are also being sought for.

Principles and Methods in the improvement of Red Clover

In the clover plant, cross-fertilization is obligatory, that is pollen from one individual is necessary for the fertilization of another. Pollination is ordinarily effected by bees which travel from plant to plant in search of honey and carry the pollen with them.

The fact that at least two different plants are required in the production of seed renders it practically impossible to produce sorts which are absolutely constant and uniform in character since each single plant may be said to constitute a distinct strain. Crossings between different strains always give a variable progeny. Experience at Svalöf has shown however, that it is possible to attain a sufficiently high degree of purity and constancy in clover to meet all the important requirements of practice.

In view of the inability to apply the pedigree culture system to this crop, a system of *mass-selection* is commonly used. Thus in seeking for hardier strains, seed is collected from plants which have come through the winter and spring with least damage. This seed is sown on an isolated plot *en-masse* and the progeny carefully studied. If the latter proves promising, a seed crop is taken, part of the seed being preserved in its present state of purity for a possible future use, the remainder being sown on a trial plot adjoining others for comparison.

In the choice of initial plants great care is exercised in seeing that these are as nearly alike as possible in all important particulars. Were plants of widely different character chosen as "mothers" the resulting progeny would present a motley collection of types. Obviously, the fewer the number of mother plants considered the more quickly will constancy be approached.

Multiplication of superior types.

When a sort has been carefully tested in comparative trial plots and in the laboratory for a sufficient number of years and has shown itself worthy of distribution, a multiplication is made of the original seed which has been preserved during the intervening period. The necessity of using such seed will be apparent when the dangers from crossing between plots which adjoin each other are taken into consideration.

Grasses.

Very little grass seed is grown in Sweden. Even Timothy seed which can be produced with comparative ease, is imported in large quantities (1½ million pounds yearly), a good deal of this seed coming from North America.

Seed of Orchard Grass, Rye Grass and Tall Oat Grass is procured chiefly from France, England, Australia and America. Meadow Fescue is obtained for the most part, from North America although this seed is produced in a small way in many places throughout Denmark.

In experiments at Svalöf, Swedish-grown Timothy seed produced 15% higher yield than that from North America despite the fact that the Swedish material used in this comparison had not been specially selected.

Orchard Grass seed imported from Denmark has been found to give better results than that from Germany and especially that from Australia while Meadow Fescue seed from Denmark has also proven superior to that from other foreign sources. The differences in seed from different countries is striking and demonstrates the need of special care when importing seed.

Principles and Methods of breeding in grasses.

In the prosecution of improvement work with grasses the principles to be observed are somewhat different from those recognized in the case of clovers or of cereal grains. In the latter case each plant fertilizes itself, with comparatively rare exceptions. In grasses, on the other hand, the flowers open before fertilization takes place, thus allowing the pollen to be carried by the wind from flower to flower and from plant to plant. The result of this peculiar arrangement is that while cross-fertilization is not obligatory as in clover, yet a large proportion of the flowers become cross-fertilized and consequently produce seed of hybrid character. Such seed when sown, necessarily gives a mixed and variable progeny. Some plants of this progeny may, if fertilized with their own pollen, breed true; others, (heterozygous forms) will "split up" in any case. By reason of this fact there is to be found

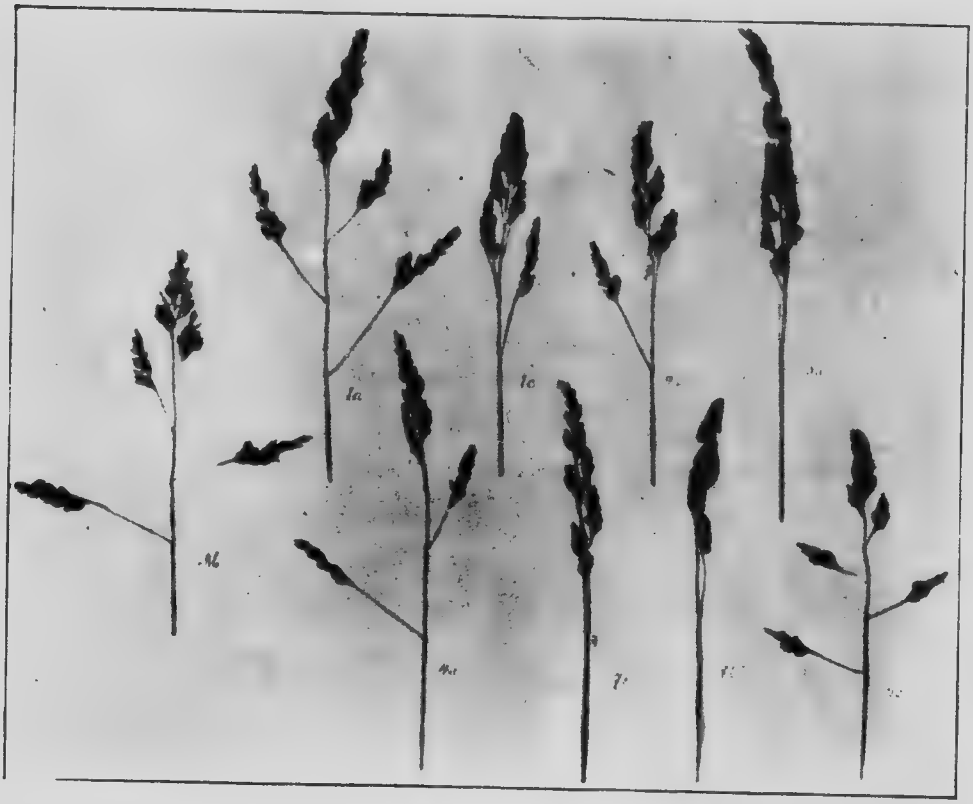

Photo by H. Witte.

FIG. XLVII.—*Orchard Grass:* Average panicles of mother plant (M) and a number of its progeny. Note variable character of the latter (82, p. 29).

in grasses an unusually great multiformity of distinct biotypes which may be distinguished by differences in physiological as well as in morphological characters, thus (82, p. 4):—

A. Morphological Characters

1. Length of stem.
2. Thickness of stem.
3. Degree of stooling and position of stems.
4. Size, position and profusion of leaves.
5. Color of leaf.

6. Hairiness.
7. Form, appearance and size of spike or panicle.
8. Development of spikelets, glumes and spikelet clusters

B. Physiological Characters

1. Hardiness
2. Time of maturing.
3. Resistance against disease
4. Withering down of leaves.
5. Aftergrowth.
6. Stiffness of straw.

A. Regarding Morphological Differences in Grasses

Great differences are to be found between different types of *Timothy* in regard to *length of stem*, even when such types are grown under essentially the same conditions. Thus, careful measurements of a large number of individuals made by Witte in the summer of 1908, revealed a variation in this character of from 50 to 130 c.m. (82, p. 6).

Investigations made with a view to determining the hereditary qualities of different types has shown that while it is practically impossible to maintain permanent constancy in such cross-fertilizing plants as grasses, hereditary gradations in the length of stem in Timothy undoubtedly occur. One of the most striking of these gradations studied at Svalöf was a dwarf type (No. 309, 1907), which maintained its dwarf habit in succeeding generations in a striking manner.

In certain other grasses such as Orchard grass and Tall Oat grass, different types in regard to length of stem have also been noticed, although the differences have not been so great as in the case of Timothy.

It has been found difficult to determine whether or not there exist hereditary differences between different forms of the same species in regard to degree of *stooling*, although investigations seem to indicate that such differences do exist.

As regards *size of leaf*, Witte distinguishes four main types, viz.:—(1) broad and long; (2) broad and short; (3) narrow and long; (4) narrow and short (82, p. 65). The size of leaf is naturally of great practical importance in view of the extent to which it determines the value of a sort for fodder purposes.

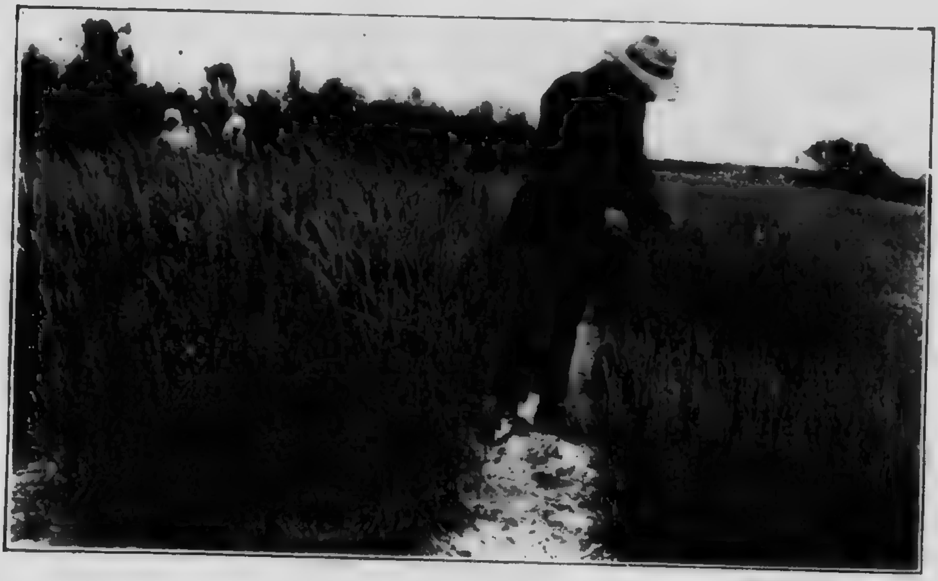

Photo by L. H. N.

FIG. XLVIII.—Timothy cultures at Svalöf showing (in the foreground) a dwarf race.

Probably the greatest variability in grasses is to be found in the character of the spike or panicle. This varies in size, form, stiffness and compactness. As in the case of cereal grains, no correlation is found between length of spike or panicle and length of straw. Thus in two races of Timothy which possess practically the same length of straw one race may have a considerably longer spike than the other. (See Fig. 49, f and g.)

On the other hand there is found a certain relationship between the length of stem and length of spike *within the one individual*. This is clearly shown in the following table which deals with Timothy (82, p. 29):—

Length of spike in c.m.	Length of straw in c.m.									Total
	20	25	30	35	40	45	50	55	60	
0·5	2	4	..	..	..	..	..	..	..	6
1·0	4	6	6	8	9	..	..	..	..	33
1·5	.	1	10	10	15	6	..	..	..	42
2·0	.	1	1	3	15	14	8	..	..	42
2·5		..	..	1	6	21	5	1	..	34
3·0		..	..	..	4	17	10	5	..	36
3·5	..	..	..	..	1	2	9	3	1	16
4·0	..	..	..	..	..	2	3	1	..	6
4·5	.	..	.	.				..	..	..
Total	6	12	17	22	50	62	35	10	1	215

Between the long and short spiked types in Timothy are to be found a whole line of gradations which are generally regarded as being hereditary.

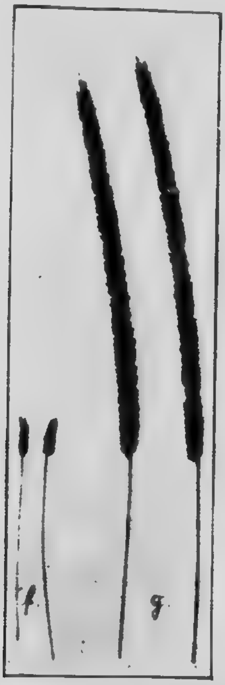

Photo by H. Witte

FIG. XLIX.—*Timothy:* Spikes from different biotypes. (⅓ nat. size.)
(82, Fig. 21 f. g.)

A great variety of panicle types have been found in Orchard grass. These are distinguished chiefly by:—

(a) Length.
(b) Length and position of the lower branches at time of maturity.
(c) Stiffness both of rachis and branches.
(d) Size of the spikelet clusters.

As in the case of Timothy, a long line of hereditary gradations are to be found between the shortest and the longest panicled types as indeed between types which are distinguished by other characters. Modifications, due to such factors as soil and season, are also very much in evidence in the case of this grass, a fact which renders it difficult to always say with assurance whether or not a given individual represents the peculiar characteristics of a distinct biotype, or whether it is simply a temporary deviation (modification) from the biotype to which it actually belongs.

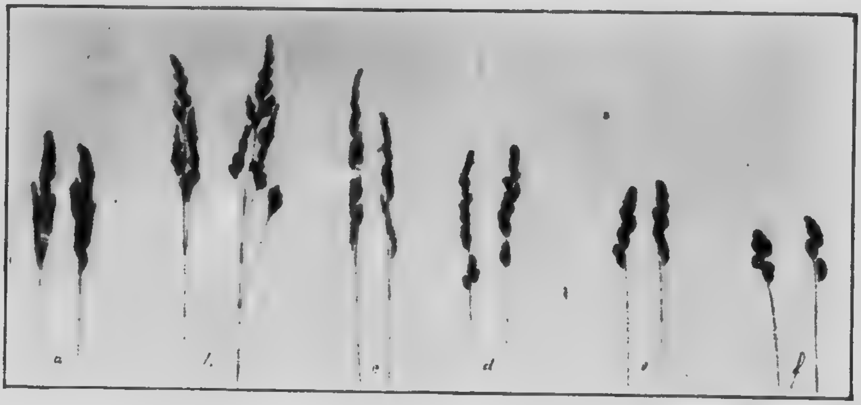

Photo by H. Witte.

FIG. L.—*Orchard Grass:* Average panicles from different biotypes (82, Fig. 25).

Variations, or more properly "gradations", are also to be found in the character of the spikelets. The glumes may differ in form and color as well as in the length and character of the awn which they bear. Different types of seed, both as regards color and form, are likewise more or less abundant.

B. Regarding Physiological Differences in Grasses.

Most cultivated grasses are fully hardy at Svalöf although at the northern station at Luleå, Ulander has found marked differences to exist between different lines within the same species (77, p. 41). Witte has also made some interesting observations to the effect that different lines of Orchard grass originating from different countries have displayed different degrees of hardiness when tested at Svalöf. Thus, types obtained from Denmark were found to be almost universally more delicate than those originating from Switzerland (82, p. 56).

The time at which a grass sort is in condition to cut is often a matter of great practical importance. This is especially the case when it is to be grown with clover as both crops should be in the best condition for cutting at the same time. While considerable difference in time of ripening between certain lines of Timothy has been noted, yet the greatest difference has been found to exist in the case of Orchard grass.

In regard to resistance against rust the differences between different lines in the case of most grasses, are exceedingly striking. The most common rust in Orchard grass is said to be "rust-spot" (*Uromyces dactylidis* Orth). When at Svalöf, the writer was struck by the fact that certain lines of the above grass seemed quite resistant against this disease, while others, immediately adjoining, were very badly attacked. According to Witte the relationship between resistant and susceptible lines in the successive years of their existence is quite uninterrupted. In the following table it is also shown that susceptibility to this disease is apparently an hereditary character, thus (82, p. 60):—

No.	Mother Plants.		Progeny.		
	Rust condition.		No. of individuals	Rust condition.	
	1910	1911		1910	1911
1	None	None	18	None	None
22	"	"	57	"	"
92	"	"	45	"	"
738	In 1908 badly	attacked.	33	Generally rusted. One individual free.	3 slightly rusted. 1 free. 30 rusted.
765	——	None	42	Generally rusted. 1 free.	11 free. 20 somewhat rusted. 11 badly rusted.
769	Somewhat rusted.	Somewhat rusted.	39	Somewhat rusted.	31 free. 6 somewhat rusted. 2 badly rusted.
806	None	None	42	Inconsiderable	39 free. 3 somewhat rusted.
287	"	Inconsiderable	38	"	29 free. 8 somewhat rusted. 1 badly rusted.

Attitude of the successive progeny of different lines of Orchard Grass toward rust.

In Timothy, timothy-rust (*Puccinia Phlei-pratensis* Erikss. and Henning) is regarded as the most serious pest. While the different cultures which the writer examined at Svalöf, clearly exhibited different attitudes toward this disease, the differences were not so striking as in the case of Orchard grass.

From the above discussion of the variability of grasses it follows that one of the first steps in practical breeding work is to test the constancy of those mother plants which are isolated for special investigation. This can obviously be done only by providing adequate protection against cross-fertilization and sowing the seeds in separate culture for a sufficient number of generations.

In conducting this test it is desirable to procure as much seed as possible from the plant under investigation since the larger the culture sown, the smaller will be the experimental error and consequently the more reliable will be the result. In grasses it is an exceedingly simple matter to augment the vegetative system by dividing the roots. Each tiny division becomes a small plant which ultimately may produce practically as large a growth as that of the original mother.

The system of numbering mother plants as well as their progeny is somewhat different in the case of grasses than in that of cereal grains owing to the fact that grasses cross-fertilize readily in nature and thus render it necessary to handle an unusually large number of individuals. All mother plants of a given kind of grass are therefore numbered *consecutively*, each plant retaining its original number in succeeding generations whether propagated vegetatively or not.

Some idea of the method of grass breeding will be conveyed by an examination of the following diagram:—

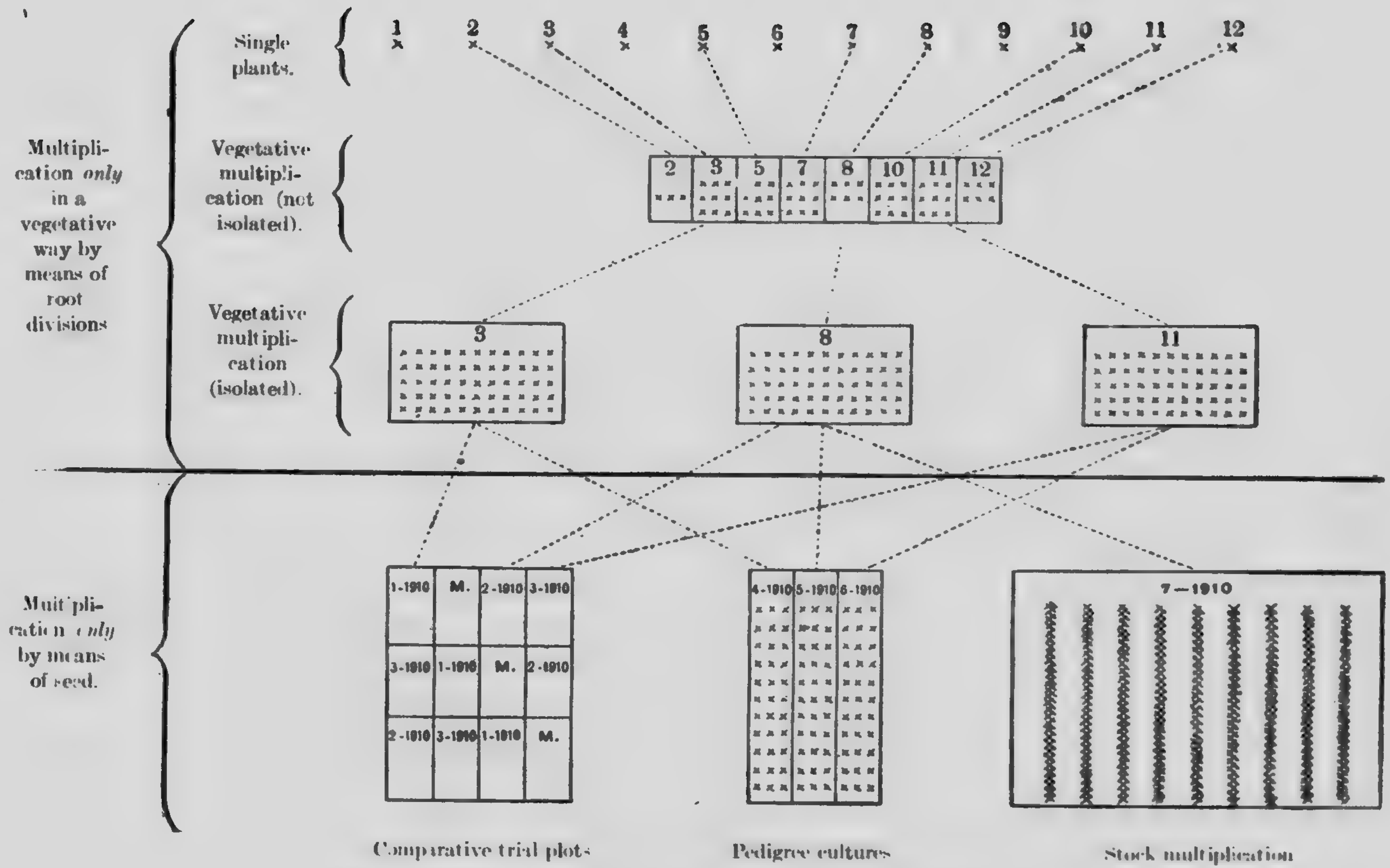

Fig. LI.—Showing method of grass breeding practised at Svalöf (83 p. 249.)

Promising plants which have been isolated for testing in separate culture are pulled up by the roots and divided in the manner indicated. All divisions (sister plants) from the one mother plant may be planted in a plot by themselves, sufficient room being allowed between each to permit of their proper development. The location of this plot should be such as to safe-guard the plants from cross-fertilization by other sorts.

Photo. by L. H. N.

Fig. LII.—View from tower of main building Svalöf, showing pedigree grass plots.

During the following summer the material may be further increased by continuing the splitting of the year-old plants, or if there already be sufficient material, this may be subjected at once to a critical examination for variations. The seed produced from each of the plants on the above plot will be the result of self-fertilization, providing the isolation from other sorts has been adequate, since each plant came originally from the same root. The progeny of this seed in two or three successive generations is likely however, to show more or less variation just as in cereals which have been artificially cross-fertilized.

Where the variation is negligible and the strain as a whole has shown itself superior, it may be multiplied for the trade. Where the variation is too great on the other hand it is necessary to begin again from one of the single plants and repeat the above process of root-splitting until sufficient constancy is finally obtained.

When the work with grasses began at Svalöf the first efforts were directed toward collecting for investigation a large number of individual plants which possessed sufficient hardiness. This was not difficult since all the grasses under consideration grow well in Sweden. Promising individuals were found in pastures, meadows and waste places while others were obtained from cultures produced from commercial samples. In this way several thousand individuals have been brought together during the past few years although large numbers which proved less valuable have been cast aside.

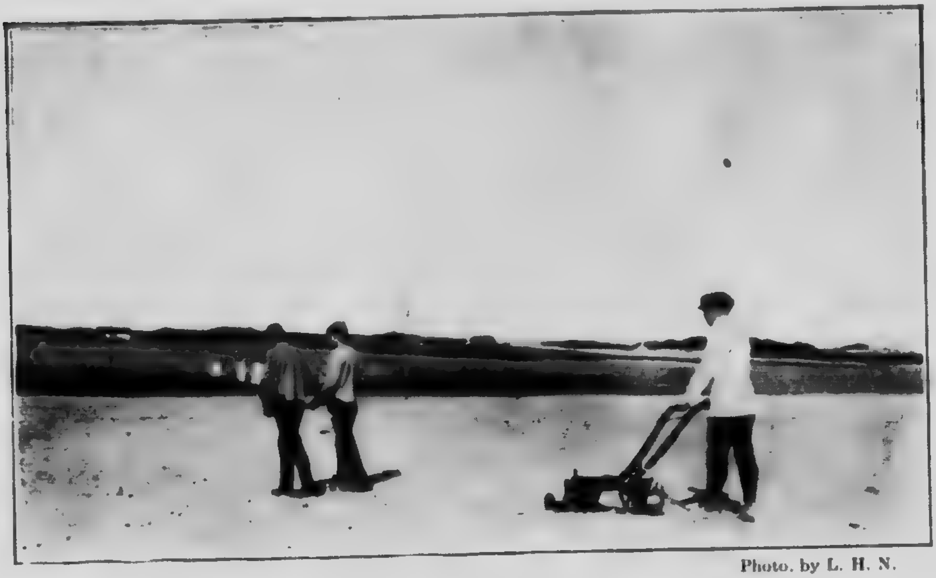

Photo. by L. H. N.

FIG. LIII.—Sowing Orchard Grass Multiplication plot in drills 0·50 m. apart (Svalöf, Aug. 10, 1910.)

Experience in the study of grasses thus far seems to indicate that the possibilities of effecting improvements of practical value seem quite as great as, if indeed not greater than, in the case of cereals.

Many types of grasses have been distinguished which possess outstanding morphological characters which are of value *as a means of identification.* Thus the different degrees of hairiness of glumes, peculiarities in the types of panicle in Orchard Grass and degrees of awn development on the flowers of Timothy are all useful for the above purpose, although every imaginable combination and gradation may be found.

The inconstant character of grasses has proven a handicap in breeding work, although a great many individuals have been isolated which were sufficiently constant from the beginning for all practical purposes.

Results obtained with grasses.

Of *Timothy* a large number of forms have been studied. Twelve to fifteen of these have reached the large comparative trials where results, while yet incomplete, tend to show that progress is being made in various directions. The characters which are sought for in this plant are:—long and stiff stems, rich, long and broad leaves and a quick abundant after-growth. In other words a *high yield of fodder* is desired.

Photo by L. H. N.

FIG. LIV.—Dr. Witte examining individual plants of Orchard Grass for constancy.

Of *Orchard Grass* twelve sorts have qualified for admission to the large comparative trials. The characters which are sought for in this grass are:—perfect hardiness, high yielding power, abundant after-growth, ability to withstand the attacks of rust and above all, late development. Great differences have been found between different strains in regard to the latter point. Thus a sort bearing the number *633* matures about 14 days earlier than another strain registered as No. *22*. The work with this grass has thus far resulted in the isolation of a new sort (*No. 42*) which has proven to be perfectly hardy, high yielding (in 1908 trial plots gave 20% higher yield than did the best Danish commercial sample), appears to be resistant against rust and is from 10 to 12 days later maturing than the common commercial variety (81, p. 328).

Of *Meadow Fescue* four new sorts, together with a sample of commercial seed from Denmark, were sown in comparative test plots in 1909. In 1910 one of these (*No. 24*) gave about 20% higher yield than the Danish stock.

In view of the probable introduction into commerce in the near future of new grass sorts, Witte urges the necessity of conducting local trials in different parts of the country in order to determine those sorts which are best suited to the various conditions.

Local trials.

Some idea of the nature and extent of the work with grasses and clovers at Svalof may be gained by examining the following tables giving a summary for the years 1908, 1909 and 1910:

Number of grass plots.

Sort	Comparative trials			Preliminary trials			Pedigree cultures			Total	Number of original plants
	1908	1909	1910	1908	1909	1910	1908	1909	1910		
Orchard Grass	313	42	54	23	59	42	100	42	16	682	378
Timothy	78	49	66	45	47	32	34	24	15	381	242
Tall Oat Grass	..	16	16	10	14	18	15	24	..	143	313
Meadow Fescue	4	12	16	12	8	13		..	..	65	42
Other Grasses	9	..	16	66	27	17	5	..	..	140	421
	404	110	168	156	146	122	184	90	31	1411	1396

Number of Clover Plots.

Sort	Comparative trials			Preliminary trials			Pedigree cultures			Total
	1908	1909	1910	1908	1909	1910	1908	1909	1910	
Red Clover	150	75	114	115	46	140	7	23	35	855
Alsike Clover	..	..	27	11	..	17	..	8	..	63
White Clover	..	..	25	..	5	..	..	..	..	30
Alfalfa	27	..	..	8	..	..	..	8	10	53
Other Legumes	..	..	..	..	4	4	..	..	..	8
	177	75	166	134	55	161	7	39	45	1009

7. Potato Breeding*

Potatoes are grown in Sweden for four distinct purposes, viz.,—for *cooking*, for the *production of commercial starch*, for *cattle food* and for the *manufacture of spirits*.

For cooking purposes quality and flavor are first essentials; for the production of starch, sorts are required which are particularly rich in this ingredient, while for cattle food, sorts which are high-yielding but not necessarily of high quality are sought. In all cases of course productiveness is a primary requisite.

The average annual production of potatoes in Sweden during the period 1891-1900 is given as approximately 2,700,000,000 pounds. The average yield per acre during the years 1891-1900 amounted to 16,607.1 pounds as against 19,916.7 for the whole of western Europe.** During the past few decades the cultivation of potatoes in Sweden has not materially increased, a fact which is believed to be due in part at least to the decrease in the manufacture of spirits. The importation of potatoes on the other hand, while not large, is nevertheless said to have been on the increase. This fact perhaps more than any other, served to draw the attention of the Swedes to the unsatisfactory position of the potato growing industry within the country and indicated the need, not only for more intelligent methods of cultivation, but for better material in the way of sorts which were better suited to Swedish conditions and which possessed greater power to resist the many diseases which attack this crop. In 1903 the Association at Svalöf accordingly took up potato-improvement work as a special branch of its activities with Mr. Joh. F. Lundberg as expert in charge. Owing to certain unavoidable hindrances however, the normal development of this work was delayed until about 1908, since which time it has advanced rapidly.

Principles of Improvement in potato breeding.

In the prosecution of potato work the principles observed are somewhat different from those recognized in the case of cereals and pease. In the case of the latter crops reproduction is entirely by means of seed which reproduces true and for the most part without hereditary variation, providing natural crossing does not occur. In the case of the potato on the other hand, reproduction commonly takes place in a *vegetative* way by means of tubers. These are simply specialized parts of the underground stems stored with starch and covered with buds or "eyes." When the tuber or a portion thereof is planted under favorable conditions, the buds begin to grow, the food being at first drawn from the tuber itself but eventually from the soil.

While the peculiarities of the mother plant are ordinarily reproduced by means of tubers, without any apparent deviation, yet variations frequently occur. These variations are commonly regarded as modifications induced by external agencies such as soil, climate, food supply and disease. Whether or not the type may be changed by the selection of such modifications has long been a matter of much speculation. In his work with barley and beans

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* The data on work with potatoes as submitted herewith, have been obtained chiefly from publications, including annual reports, by Lundberg.

** "*Sveriges Land och Folk*," Gov't. Printing Office, Stockholm, p. 537.

Johannsen showed, as we have already noticed (See page 29) that modifications within a "pure line" are not transmissible and therefore cannot be utilized in the improvement of the race. Since reproduction in potatoes by means of tubers is really reproduction in a pure line it would seem that no improvement is possible even in this crop by the selection of "plus" fluctuations. That improvement in potatoes has actually been made at Svalöf by a careful selection of tubers seems fairly well established, although there has not yet been sufficient time to show absolutely whether or not these apparent advances in all cases are real or imaginary. If real, they may be due to some sort of mutation, as changes belonging to this category are believed to take place in such vegetative parts.* On the other hand, they may be only imaginary since the enormous effects of climate, soil and season may have so confused the results as to make it appear as though progress had actually been made.

Correct conclusions are possible only after properly controlled experiments. In order to throw more light on this problem of variation as it affects vegetative parts, material for investigation was obtained at Svalöf from the sort *No. 1041*. This sort gave a very satisfactory yield with an average per cent of starch. The tubers were oval but somewhat irregular with large eyes of medium depth and with fine netted skin. The color was blue-violet or almost black. In 1905, eight tubers from the above sort were planted. These gave well developed plants which showed some slight differences in the character of the leaves. Three of these deviating plants were marked and harvested separately, the hills being labelled *a*, *b*, and *c*. These were preserved and used the following year to plant three separate plots. An examination of these plots showed that the peculiarities of the mother plants had been quite accurately reproduced in each case. An examination and analysis of the tubers from each plot was made and served to further establish well defined differences. The flesh of *c* was a deep violet, while that of *b* was only faintly colored. The starch content of *c* was 17.1%, but with *a* and *b* reached 17.7%. The yield of *c* was only 25,200 kg. per hectare while that of *a* was 29,160 and that of *b* 33,120. In the following year (1907) these relative differences were maintained, *c* giving 13,680 kg. and 15.4% starch, *a* giving 18,000 kg. and 16.3% starch and *b* giving 21,240 kg. and 16.4% starch.

In 1908 a further comparison was made but this time at two different centres, viz., Svalöf and Böketofta. The results of this test are recorded as follow (24, p. 214):—

	(Svalöf).			(Böketofta).		
(a)	23,580 kg. and	16.5%	starch.	21,600 kg. and	16%	starch.
(b)	22,680 “	16.4%	“	19,980 “	15.7%	“
(c)	14,440 “	13.8%	“	13,320 “	13.5%	“

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* Numerous examples are cited by different investigators, of the production of new sorts by means of changes which are supposed to have been of a mutative character. In *Fühlings Land'w, Zeitung*, 1910, No. 16, p. 537, for example, an account is given of the production by Von Lochow of a number of sorts by the selection of such variations found in the well known sort *Wohltmann*.

The differences between the above lines are significant in that all three came originally from the same plant. While it is admitted that these differences may possess very different values and may even be of different origin, they are regarded as providing a valuable means of effecting improvement even to the extent of producing quite new sorts. In discussing the origin of these tuber variations Lundberg says "They might quite easily arise as a result of certain diseases which attack certain plants but spare others; by selecting those which have withstood the disease, decided progress may often be made. On the other hand, variations in such vegetative parts as tubers may be of a deeper nature, arising through some spontaneous change in the character or 'life' of the tuber itself. Such a phenomenon is known as *tuber variation.*" In accordance with this point of view one of the main methods of potato improvement employed at Svalöf has been and now is the *continuous selection of desirable hills and tubers.*

Photo by L. H. N.

FIG. LV.—Digging pedigree plots of potatoes taken from *Magnum Bonum, Prof. Maerker,* etc.

Production of sorts from the true 'seed.'

Another method commonly empolyed in the production of new sorts is by means of the *true seed.* This seed may be obtained either by artificially crossing different sorts or it may be taken directly from plants in the field which have been cross-fertilized naturally. The latter course has been abandoned at Svalöf since experience has shown that success can be confidently looked for only when plants whose values and peculiarities are known, constitute the parentage. The first artificial crossings in potatoes were made at Svalöf in 1903 since which time the number has greatly increased.

The process of crossing in the case of potatoes is extremely simple as the flowers are large and the organs easy of access. The principal difficulty is to find sorts which are properly equipped to participate in this process, since the production of pollen in the case of this plant is very irregular and often meagre.

Photo by L. H. N

FIG. LVI.—Mr. Lundberg crossing potatoes

The seeds of the potato are small and numerous being imbedded in the pulp of the "potato-balls" or "potato-apples." The latter are about the size of large marbles and are suspended from the upper portions of the stalk on short stems or pedicles. When the balls are ripe they are gathered and allowed to dry. The seeds are then squeezed out and in early April are planted in boxes in the hot house. The young plants are usually transplanted once or twice before being planted in the open. By this time all danger of frost is over and both the ground and the air are warm. The tubers produced from these seedlings the first year are usually quite small, about three years being required to attain full size. At the close of the first season's growth the product of each seedling plant is harvested separately (See Fig. 57) and its tubers carefully preserved for the following year's planting. When this time arrives each lot is planted by itself in short rows and elimination goes on from this time forward. The time required in discovering the best combination resulting from a cross naturally varies greatly owing to the many factors which must be taken into consideration and to the unusually large experimental error which has to be reckoned with. The field trials must be very carefully conducted and each lot or "line" must be allowed duplicate or triplicate plots. Tests must also be conducted in the laboratory where the final judgment as to quality, shape and general type is made. After about the third year from the seed, when the tubers have attained normal size and type, the methods of conducting field trials with seedlings are comparable in all essential particulars with those followed in testing ordinary tuber selections made from old races. Empirical methods in determining which combination or "variation" as the case may be, is best, must prevail in each case and these must be practised for a sufficient number of years to allow a safe judgment to be made. Generally speaking from four to six years is required before the value of a sort can be pronounced upon.

Preliminary studies.

When the work of potato improvement began at Svalöf there was first collected a large number of old sorts for examination and testing. Thus in 1903 there were planted a collection of 420 sorts obtained from the Agricultural College at Ultuna while about 100 newer sorts were purchased from certain foreign breeders. As much of this material as space would allow was again planted in 1904 and the whole lot delegated to Dr. M. O. Malte for a critical botanical examination.* Copious notes were made on this material and about 300 plants were pressed for further study. During the growing season notice was taken of the time of flowering and of maturing as well as of the attitude of the different sorts toward disease. In 1904 a public request was made through the local newspapers for material for special exploitation. In this way not less than 150 lots from 89 different growers were obtained. The intensive study to which the above material was subjected, provided data which proved of great service in laying the foundation for systematic work in the amelioration of this crop. It also served to disclose the great number of varieties and types which were scattered throughout the country and the difficulty of classifying these into groups. It showed indeed that the number of so-called sorts then in circulation was much greater than in the case of other agricultural plants. This is attributed to the fact that the potato cross-fertilizes naturally with comparative ease and that a large

Photo by L. H. N.

FIG. LVII.—F_1. (first generation hybrids) from different potato crossings number of sorts are continually being originated from this cross-bred seed. In view of the numerous combinations which are possible from a single crossing the production of new sorts is quite a simple matter. The obtaining of *something better*, however, is an entirely different and an immensely more difficult problem.

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* Dr. Malte is now an officer (Agrostologist) of the Experimental Farms' Branch of the Dominion Department of Agriculture, Ottawa, Ont.

Starch determination.

Another important quality in the potato, which is investigated carefully at Svalöf and other Scandinavian centres, is the starch content of the tuber, since this is regarded as a sort character of importance. The determination of starch naturally has its greatest value when sorts for the manufacture of the commercial product are being sought. In this case the actual *quantity of starch per acre* is the basis of valuation. In *cooking potatoes*, on the other hand, high starch content is not of great importance but rather is likely to be the reverse as it may be inimical both to taste and cooking quality. As a general aid in the work, however, the determination of starch content has proven of great assistance.

On account of the diminutive size of the sample available for testing from each sort, "Stohmann's" method of analysis has been used. This method is briefly as follows:—A number of tubers from a given lot are taken and weighed after being thoroughly washed and dried. They are then dropped into a glass jar of water so equipped as to indicate exactly the water displacement. In this way the specific weight is quickly obtained. Since the specific weight of potato tubers has been found to stand in very close relationship to the starch content, a scale has been devised which indicates at a glance the per cent of starch contained in tubers of a given weight.

The starch content of potatoes is greatly influenced by soil and seasonal conditions. During dry years it is usually higher than during moist years. This is believed to be due to the difference in the inner development of the tuber during different years. Great variation in the starch content of a given sort is also induced by soils of different character. Since some sorts are better suited to certain soils than are others, the problem of how to correctly interpret starch determinations becomes a complicated one.

In his investigations in connection with this problem Lundberg has found differences in the starch content of single plants belonging to the same pedigree sort. These he believes to be due to factors other than those which are external. As an example of this sort of variation may be cited the results of investigation with the two well known sorts *Magnum Bonum* and *Wohltmann* (23 p. 94.). The material for this investigation came in each case from a single plant chosen on the basis of form of tuber and general appearance of plant. The following table indicates the results of the analysis:

Starch content of tubers of different plants of the same sorts during different years.

Sort	Year	Plant	Pl. 2	Pl. 3	Pl. 4	Pl. 5	Pl. 6	Pl. 7	Pl. 8	Pl. 9	Pl. 10	Pl. 11	Pl. 12
Wohltmann	1907	18.1	12·6	17·3	17·1	16·0	20·3						
	1908	20·5	21·1	19·8	20·5	20·5.							
	1909	19·3	19·3	19·7	20·4	18·0	23·5	21·9	22·2				
	1910	20·8	20·3	20·8	18·8	20·7	21·1	21·5	21·4	20·5	19·5	21·1	22·5
Magnum Bonum .	1907	16·3											
	1908	18·4	18·2	18·4	18·7								
	1909	15·5	15·2										
	1910	17·2	17·1	17·3	18·2	18·1	17·2	17·7					

An examination of the above table will show among other things, that in the year 1910 the starch content of *Magnum Bonum* ranged from 17·1% in plant 2 to 18·2% in plant 4, or a difference of 1·1%, while in Wohltmann the variation was considerably greater namely, from 18·8% in plant 4 to 22·5% in plant 12 or a difference of 3·7%

Not only have differences in the starch content of tubers from different plants been discovered but distinct deviations have been noted in the tubers produced *in the same hill.* The accompanying table shows the weight and per cent starch of each of the tubers produced by single plants belonging to four different sorts grown in 1910 (23 p. 95.). Differences between the different plants in regard to starch content may again be noted here:—

Weight and per cent Starch of different tubers produced by the same plant in 1910.

Variety	Plant No.	Tuber 1 Wt. (grs.)	Tuber 1 Per cent. starch	Tuber 2 Wt. (grs.)	Tuber 2 Per cent. starch	Tuber 3 Wt. (grs.)	Tuber 3 Per cent starch	Tuber 4 Wt. (grs.)	Tuber 4 Per cent. starch	Tuber 5 Wt. (grs.)	Tuber 5 Per cent. starch	Tuber 6 Wt. (grs.)	Tuber 6 Per cent. starch	Tuber 7 Wt. (grs.)	Tuber 7 Per cent. starch	Tuber 8 Wt. (grs.)	Tuber 8 Per cent. starch	Tuber 9 Wt. (grs.)	Tuber 9 Per cent. starch	Tuber 10 Wt. (grs.)	Tuber 10 Per cent. starch
Wohltmann.	1	167	21·6	132	20·0	122	22·2	88	20·0	80	23·1	78	23·4	63	19·4	27*	27·0				
	2	146	22·0	130	21·6	96	22·0	64	26·4	63	19·5	62	18·4	43	24·4						
	3	180	24·2	166	23·1	129	21·7	104	23·3	92	19·5	45	27·4	44	25·0						
	4	138	21·6	121	24·2	111	24·2	102	21·5	93	22·0	93	25·9	60	23·3						
Magnum														39	20·2	34	19·2				
bonum	1	148	19·2	100	20·0	70	18·4	59	18·4	49	18·2	43	19·2	47	18·4	44	18·4				
	2	77	19·3	70	19·2	64	19·3	59	19·4	56	19·2	56	19·2	51	19·9	40	20·7				
	3	100	18·7	93	19·2	85	19·2	70	19·2	63	19·8	62	19·4	45	19·9	38	19·7				
	4	106	19·2	100	18·4	87	18.4	84	18·5	76	19·2	76	19·4	33	18.8	33	16·6				
No. 2172.....	1	95	17·1	84	17·7	66	16·8	45	17·3	41	16·8	37	18·6	60	17·0	52	17·0				
	2	106	16·6	99	17·3	71	17·9	66	16·6	63	16·8	62	17·0	44	17·9	43	17·1				
	3	92	17·9	84	17·9	76	16·4	73	17·3	71	16·9	59	18·4	54	11·1	39	19·3	34	20·0		
No. 349......	1	208	14·7	136	14·7	133	14·2	81	17·7	81	14·7	62	18·2	52	20·0	51	18·8	44	15·1	42	20·9
	2	111	19·0	95	17·5	87	19·0	85	17·5	75	18·0	63	16·6	54	15·6	41	18·4				
	3	196	15·6	194	16·4	152	18·2	117	18·4	88	20·0	61	19·2								

*This tuber was small, round, of good shape, and strongly netted, which latter appears to be due to the fact that this particular tuber was among the earliest to develop.

The above table serves to reveal not only differences between different tubers produced by the same plant, but differences between the different plants and between the different sorts. The variation within *349* for example, is clearly much greater than that within *2172* or *Magnum Bonum*. It will also be noted that the size of the tuber seems to have very little influence on the per cent starch, although small potatoes are not infrequently low in this material owing, no doubt, to their imperfect development.

In view of the above behaviour of individual tubers and individual plants in respect of starch content great care must be taken in the choice of material for analysis. Only "pure-lines" can be investigated to any purpose and of these, representative hills must be taken.

Field trials of potatoes.

The field trials of potato sorts at Svalöf are laid out in two series. The first is called the *small or preliminary sort trials*, and the latter the *large comparative sort trials.* The first series accommodates the newly produced sorts including seedlings and those which have been isolated by selection from an ordinary variety. The second series receives the most promising sorts and makes the final pronouncement upon them.

Photo by L. H. N.

FIG. LVIII.—Digging comparative trial plots of potatoes and taking notes on character and condition of the tubers. Note stakes placed at hills during growing season on account of some peculiarity of growth or evidence of disease.

In the preliminary trials eight whole tubers of each sort are planted. This makes eight hills. For the sake of convenience these eight hills are arranged in two rows of four hills each. During the growing season careful notes are taken as to the uniformity, character, attitude toward disease and general behaviour of each sort, and on this basis many exclusions are made.

The large comparative sort trials are laid out more systematically and in a manner very similar to that followed with the other crops operated with at Svalöf. Here each sort occupies from two to four different plots which are alternated with some standard sort such as *Magnum Bonum*, as a check. Formerly each plot occupied 25 Kvm. (269 sq. ft.), but this was later reduced to 12.5 Kvm. (134.5 sq. ft.) on account of the difficulty of finding soil of sufficiently even quality over so large an area. Each plot of the area indicated accommodates nine rows of five hills each making 45 hills in all. The nine rows are 0.60 m. (23.6″) apart while the hills are .45 m. (17.7″) apart in the row. All sorts which seem promising are included in the above comparative trials as soon as possible.

Some idea of the division and extent of the work with potatoes is afforded by the following table, which gives the identity and exact number of the different cultures operated with during the years 1904-1911 inclusive:—

Potato Work at Svalöf from 1904–1911 inclusive (24 p. 216).

	1904	1905	1906	1907	1908	1909	1910	1911
Preliminary trials with sorts produced by crossing......	289	669	766	949	1,060	1,243	1,904	655
Older sorts under investigation.	942	660	337	335	315	293	178	184
New lines from single tubers...	..	..	..	58	111	..	152	..
Large comparative sort trials..	..	..	..	120	236	177	190	150
Multiplications	..	..	173	60	9	145	34	42
Number per year	1,231	1,329	1,276	1,522	1,731	1,858	2,458	1,031

Local sort trials.

In view of the ease with which the potato is affected by the character of the soil in which it grows, local trials of different sorts have been conducted on rather an extensive scale. The locations for these trials have been very carefully chosen so that the main types of soil where potatoes can be grown at all successfully have been occupied. Thus, trial plots have been placed on the sand tract which extends from Landskråna towards Vombsjö south of Svalöf and on glacial clay soils, rich in humus and in good culture lying north of Svalöf. The soil at Svalöf itself is, as previously explained, a rather light, sharp clay loam. The above trials have not only proven useful in connection with the regular work, but have revealed many interesting and valuable peculiarities of the potato plant. They have shown, for example, that under certain conditions the yields may be greater than under others, while at the same time the starch may be lower. Thus at Böketofta the starch content of tubers has been found to be almost universally lower than at Svalöf, although the yield is usually higher. From this it is inferred that the internal development of the Böketofta grown tubers is not so far advanced or perfect as in the case of tubers grown at Svalöf despite the superiority in size of the former.

A noteworthy exception of the above case was afforded during the cold wet year of 1907, when the yields at Böketofta were much more seriously effected than were those at Svalöf and at Gisslebergа where the soils were better suited to withstand the conditions indicated. The following table gives the results for this year and is self-explanatory:—

Yields of tubers and per cent starch of different sorts grown on different soils in the cold, wet year of 1907 (24 p. 209).

No. of Sort	Svalöf (Clay Soil)		Gisslebergа (Sand Soil)		Böketofta (Vegetable Clay)	
	Tubers (Kilo. per hectare)	Per cent Starch	Tubers (Kilo. per hectare)	Per cent Starch	Tubers (Kilo. per hectare)	Per cent Starch
1189	29,070	21·4	11,350	18·0	12,730	16·2
1035	26,350	16·0	20,080	19·1	13,710	16·6
1060	24,820	13·1	15,810	16·6	12,070	12·0
1031	22,610	13·5	14,960	17·1	9,520	13·4
1077	22,100	17·5	17,340	21·4	14,280	17·1
1108	20,570	14·9	15,810	21·0	13,090	17·3
1156	20,540	18·9	11,560	22·9	11,200	19·4
1118	20,120	14·9	18,870	21·0	9,800	17·3
1119	20,080	20·6	14,280	21·8	8,160	16·3
1015	19,210	14·3	17,050	17·2	15,640	12·2
1050	19,210	14·9	17,340	21·1	12,580	16·9
1151	18,700	16·7	13,560	17·0	11,220	12·5
1191	18,530	18·3	10,540	19·1	12,410	15·3
1072	17,170	16·9	14,320	18·4	8,500	15·1
1085	16,150	14·8	20,230	16·4	13,710	12·9
1112	15,640	20·6	13,480	21·8	8,160	16·3
1083	14,960	15·2	17,190	16·4	12,410	14·0
1079	13,020	19·4	14,320	21·1	9,800	17·0
1049	12,410	15·9	15,130	18·2	10,540	14·2
1214	12,400	17·5	12,580	20·7	12,410	16·5
1014	10,370	16·0	11,560	18·1	8,670	13·6

Degeneration in potatoes. The problem of potato improvement by the selection of favorable variations is intimately linked with that of "degeneration." That potatoes degenerate or "*run out*" naturally is an idea commonly held by the great mass of growers. Many believe that this is a natural phenomenon—something to be expected and something which cannot be avoided. A new variety comes into circulation, remains in the foremost ranks for a few years or until it reaches a period of old age or "senility" and then gradually begins to decline. Such is the generally accepted idea of the life of a potato sort. That certain varieties do appear to act in this peculiar manner cannot be disputed. On the other hand, experience shows that other sorts which have been under cultivation a great many years do not appear to have lost in vigor or in productive qualities during this long space of time. A good example is afforded by the Swedish sort known as *Dala*, commonly grown in the province of Delecarlia (Dalarne). This potato is said to have been introduced about 150 years ago, yet is still one of the best sorts grown in that Province (59, p. 28). The opinion held at Svalöf regarding this important question is that there is *no period of old age in a variety of potatoes.*

The degeneration which is often noticed is believed to be due to certain factors which hinder the normal development of the plants and tubers or which invite disease. Potatoes reach their highest state of vigor and development under cool, moist conditions. Seed tubers produced under such conditions almost invariably give better results than do those grown in hotter and drier regions, owing it is thought to their greater vigor. Where potato growing is prosecuted in districts which are unfavorable to the production of strong vigorous seed tubers it is considered good practice to obtain seed at frequent intervals, from districts which are more favorable to this crop. Where this practice is not followed the vigor may gradually become weakened resulting in a corresponding depreciation in yield and quality. Similar results may likewise follow neglect, even in the best districts, to discriminate between small, poorly developed and sound seed tubers. Too often all the good sound tubers are sold or used for cooking while the poor, discarded and in many cases diseased tubers are kept for planting. Where this practice is followed there is bound to be a falling off in productiveness. The evidence at present available seems to show that *where suitable sorts are used and where suitable tubers of these sorts are utilized for seeding purposes each year, the standard of a variety may be maintained indefinitely under all favorable conditions of soil and climate.* Since some varieties are not adapted to certain conditions it is quite possible that their power to resist disease may become gradually reduced. This would seem to explain why certain varieties grown in comparison with others and under similar conditions for a number of years seem to be more susceptible to blight and other diseases than do neighboring sorts. Obviously, the main considerations are *maintenance of vigor* and *control of disease,* and this implies very careful choice of seed tubers, careful cultivation, spraying and rotation of crops. In Sweden special emphasis is laid upon the latter point. The need for care in this regard is considered even greater with potatoes than with the cereals.

Results obtained in potato breeding.

The yields and starch content of the different potato sorts investigated at Svalöf up to and including 1910, have recently been made public in an excellent summary of the work in potato breeding by Lundberg (24). The following tables are taken from this publication:—

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

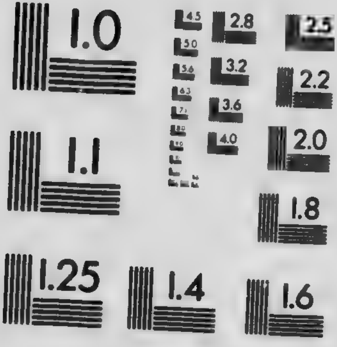

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Fig. LIX. Table of yields and Starch Contents of cooking Potatoes at Svalöf during the years 1906-1910.

	1906		1907		1908		1909		1910		1911	
	Kilograms per hectare.	Per cent. starch	Kilograms per hectare	Per cent. starch	Kilograms per hectare	Per cent starch	Kilograms per hectare	Per cent starch	Kilograms per hectare	Per cent starch	Kilograms per hectare	Per cent starch
1189,* Athene × Unica	32,400	17·0	30,780	21·4	32,760	19·2	32,940	18·3	31,500	17·2	32,076	19·0
2172, Goldball × Unica	36,720	15·4	26,460	13·3	30,600	14·9	28,620	11·4	30,600	14·3	30,600	13·8
1122, Märcker × Unica	30,600	16·3	22,860	15·6	27,360	17·7	36,540	15·6	33,840	16·5	30,240	16·4
172, British Queen	34,200	17·7	20,700	16·0	25,920	15·7	37,260	16·7	31,500	16·2	29,916	16·5
112, Up-to-date	33,480	15·4	18,720	14·9	27,900	16·0	30,600	16·4	37,980	16·9	29,736	15·9
197, Richters Imperator	30,960	20·9	22,680	19·2	19,620	18·6	36,180	17·8	35,820	21·0	29,052	19·7
1118, Jewel × Clio	32,760	18·8	21,420	18·5	26,460	17·4	29,340	16·9	30,600	19·4	28,156	18·2
143, Unica	30,960	17·0	21,960	14·9	20,520	14·9	36,360	13·4	30,060	14·0	27,972	15·2
2111, Magn. Bon. × Unica	27,000	16·6	18,360	14·6	34,740	17·3	30,600	14·8	26,280	14·3	27,396	15·5
2116, " " "	28,440	15·8	22,680	14·2	20,340	15·6	31,860	15·2	28,800	15·7	26,424	15·3
1119, Jewel × Clio	32,760	18·1	21,240	20·1	21,960	18·6	26,460	20·5	29,160	17·6	26,316	19·0
72, Magn. Bonum (Sutt.)	27,720	16·4	21,960	15·6	23,220	15·9	27,000	16·0	22,140	17·0	24,408	16·2
2045, Edelweiss × Unica	27,000	18·4	19,980	14·3	19,620	16·0	25,020	14·6	29,160	18·0	24,156	16·3
909, Ella	25,000	18·1	12,220	14·9	20,800	16·2	17,200	13 9	19,600	16·7	18,964	16·0

* The uniformity in the yield of 1189 for the five years stands, as will be seen, in striking contrast to the fluctuations in the other sorts for the same period.

Sorts.		Kilograms of tubers per hectare.	Per cent. starch.
Geheimrath Thiel....	(Not a cooking potato).	35,136	18·8
Up to date.........	(Common commercial sorts).	29,736	15·9
Magnum Bonum....		24,408	16·2
Agnelli.............		23,940	18·1
Kaiserkrone.........		22,932	16·8
1189, Athene × Clio............	(Svalöf Sorts).	**32,076**	**19·0**
2172, Goldball × Unica.........		30,600	13·8
1222, Märcker × Unica.........		30,240	16·4
1118, Jewel × Clio.............		28,156	18·2
2111, Magnum Bonum × Unica.		27,396	15·5
Marielunds.............	Old Swedish Sorts.	21,492	17·9
Gula Sörmlands.........		19,044	16·8
Dala...................		18,504	16,1
Röda Västgöta (a)......		17,748	18·5
" " (b)		17,604	19·5

Comparison in yield and starch content of the five best Commercial, Svalöf and Common Swedish potato sorts. Average from field trials at Svalöf, 1906-1910 inclusive.

As will be seen in the above table the sort *1189*, produced from the crossing *Athene* × *Clio*, is excelled in yield only by *Geheimrath Thiel*. The latter, however, is not a cooking potato but is used chiefly in the manufacture of starch so is of little interest in this connection.

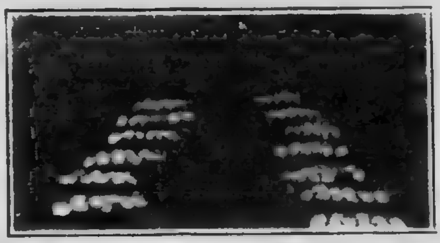

Photo by L. H. N.

FIG. LX.—Two best pedigree potato sorts thus far (1910) produced at Svalöf. Both were selected from No. 349 which in turn was taken from *Eldorada*.

Cooking Qualities.

In the breeding of potato sorts for cooking purposes great importance is attached to the following points:—taste, mealiness, size, form, depth of eye, fineness of skin, color of skin and flesh. Last but not least keeping quality is regarded as of very great importance. On the basis of these considerations many sorts which have stood high in yield are compelled to occupy a lower place.

Regarding "early" potatoes.

The breeding of so-called "early" potatoes has received considerable attention at Svalöf. By "early" potatoes is commonly understood those sorts the leaves and stems of which wither down and indicate an approaching maturity of the tuber at a relatively early date. That such a conception of an early potato sort may be quite misleading and faulty has been clearly set forth by Lundberg in the following table:—

Sorts.	Number of days from planting to maturity.	Standing of the different sort on the basis of size of tuber, on dates indicated.	
		June 30	July 8
Sharp's Victor	100	....	....
Beauty of Hebron	110	5	1
June	116	....	....
Bovee	116	2	3
Voodbury's White	116	3	4
Early Puritan	120	1	5
Alabaster	120	16	15
Roses	125	4	2
American Rose	125	6	6
Kaiserkrone	125	15	14
Almond	125	14	17
Purple and Gold	130	12	13
Low's Early	130	13	16
Goldball	134	17	18
Paulsen's July	134	10	11
Svalöfs 2142	135	7	7
" 3077	135	8	9
" 3089	135	9	19
" 3094	135	18	8
" 3204	135	19	10

Relation between time of ripening and state of development of tubers.

An examination of the above table will disclose the interesting fact that the earliest maturing sorts do not necessarily produce usable tubers at the earliest date. Thus *Early Puritan,* which is ten days later than *Beauty of Hebron,* is nevertheless shown to produce a larger proportion of usable potatoes on the thirtieth of June than does the latter, although as time advances the above condition gradually becomes reversed. The small degree of relationship which exists between time of maturity and the date on which a given sort is large enough to be used for cooking purposes is exceptionally well illustrated in the behaviour of the sorts *Rose* and *Kaiserkrone.* Although these two sorts mature at the same time the former occupies fourth place as regards the usability of its tubers on June 30th, while the latter stands almost at the foot of the list, viz., fifteenth, at this date. Experience at Svalöf thus far seems to indicate that the problem of producing early sorts possessing desirable characters seems to be associated with greater difficulties than is the case with later sorts.

VIII.—APPENDIX

As mentioned in the Preface to this paper the first essential in breeding work is to know the exact conditions of soil and climate which characterize the various regions which it is designed to serve. For this reason a brief description of these conditions as they obtain in Sweden is appended here.*

Geographical position of Swed

The country of Sweden occupies the eastern and larger section of the *Scandinavian Peninsula* which is situated in the north-western part of Europe. The exact position may be more definitely stated as being between 69° 3′ 21″ and 55° 20′ 18″ N. Lat. and between 11° 6′ 19″ and 24° 9′ 11″ E. Long. of Greenwich. It will therefore be seen that the southern extremity of Sweden is farther north than Athabasca Landing, Alberta, Canada. The entire country consequently lies farther north than the principal cultivated areas of the Dominion, 15% of the whole surface area indeed, lying within the Polar Circle. Stockholm, the Capital, is situated on parallel 59° 21″, which is slightly north of Fort Vermillion, Alberta, Canada, and south of St. Petersburg, the Capital of Russia. Sweden is bounded on the east, south and partly on the west by water, the only land boundaries being those dividing it from Finland and from Norway. The waters are: The Baltic Sea with the Gulf of Bothnia, the Öresound, the Kattegat and the Skagerack.

The length of Sweden from north to south is about 1,600 kilometres or 993 English miles. Its breadth is approximately one-fourth as great as its length. The area, according to the most recent surveys, is given as 44,786,227 hectares, or about 110 million acres. It is a little smaller than either France or Germany, but is almost half as large again as the British Isles. It may therefore be regarded as one of the larger countries of Europe. Carrying the comparison to Canada, the area of Sweden represents approximately 75% of the total land area of the province of Ontario. Only about 8½% of the surface area of Sweden is regarded fit for agricultural purposes of which area only about one-half or nine million acres is under cultivation. Of this about 8½ million acres is under field crops and the remainder under garden and pasture. Owing to the presence of extensive areas in the north which cannot be cultivated, the total per cent of agricultural land in Sweden is small. In Skåne, the leading agricultural province, not less than 60% of the entire area is under cultivation; this province contains in fact 17% of the agricultural land of all Sweden.

Statistics of 1898 show there to have been about 334,360 farms in Sweden divided as follow:—

23% consisting of only 5 acres.
66% consisting of between 5 and 50 acres.
10% consisting of between 50 and 250 acres.
1% consisting of more than 250 acres.

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* This description has been obtained for the most part from the Swedish publication entitled "*Sveriges Land ocn Folk*," 1904, Gov't. Printing Bureau, Stockholm. An English edition of this publication entitled "*Sweden, its People and its Industry*," is also available.

Sweden is divided into three main sections, viz., *Svealand*, *Götaland* and *Norrland*. The former district, roughly speaking, is composed of the provinces lying between parallels of latitude 59 and 62. This district is popularly spoken of as *Middle Sweden*, although strictly speaking it is not in the centre of the country, but rather toward the south. Götaland comprises the district south of Svealand, while Norrland represents the northern region.

Physiography.

In physical features Sweden may be said to be rather broken, the greater part of the country consisting of low granite hills covered with pine and fir, but not infrequently interspersed with fertile plains. The best part of the country from an agricultural standpoint, is found in the southern provinces. The only mountains in Sweden worthy of note are found along the Norwegian frontier. The greatest elevations within Swedish territory are found on the peaks of Kebnekajse and Sarjektjocko, which attain a height of 7,192 and 6,920 feet respectively.

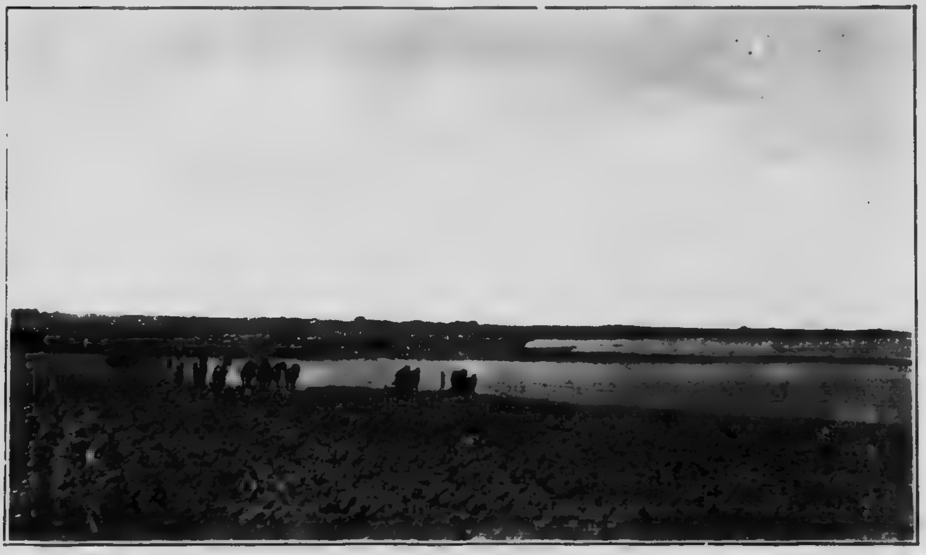

Photo by L. H. N.

FIG. LXI.—Typical landscape—"Plains of Skåne," Southern Sweden. (Lat. 55° 43'.) Preparing land for Autumn Wheat, July 14.

The very large number of lakes in Sweden forms a striking feature of the country, nearly one-twelfth of the whole surface being covered with water. The presence of so much water has an important influence on vegetation.

The geological formation of Sweden consists largely of granites, gneiss and metamorphic rocks broken through and overflowed by trap, the surface being covered with drift formation and boulders. The "Plains of Skåne" (See Fig. 61), which occupy the southernmost section of Sweden and which are noted for their excellent agricultural soil, rest on a foundation of sedimentary formations. In general character these plains are somewhat variable. Thus in certain sections where there is a covering of recent marine deposits, the surface is almost uniformly level; in other parts we find undulating and shallow valley basins separated by low ranges of hills.

Climate.

Owing to the fact that Sweden extends from north to south for almost 1,000 miles, and that the southern part is strictly maritime while the north enjoys more continental conditions, the climate is exceedingly variable. The Scandinavian Peninsula is particularly fortunate, however, in being in the wake of the Gulf Stream which skirts the coast of Norway and moderates the temperature not only of that country, but also of Sweden lying further inland. The climate is therefore not so severe as the northern position of the country would suggest.

Two other causes serve to accentuate the climatic differences of Sweden. The first is that the Northern part of the country is separated by the north Scandinavian Mountain Range from the warming effects of the South West winds. The second is that Northern Sweden possesses a higher altitude than does the Southern part. As a consequence of this the average annual temperature of the most Northern part is somewhat below freezing point (32° F.), while on the South Western coast it is around 45° F. At Haparanda north of Luleå on parallel 65° 50″ almost opposite Ft. Yukon, Alaska, and just South of the Artic Circle, the average temperature during February, the coldest month of the year, is about 10° F. above zero, although it may drop to 40° below for a short period. At Stockholm the average temperature for the same month is only about 6° of frost, while at Svalöf it is only 2°

July is the warmest month in Sweden. The average temperature for this month at Haparanda is 59° F., being only 4.7 degrees lower than London, England, and 1.3 degrees lower than at Stockholm. The absolute summer maximum is about 86° F. in most years and at the majority of the stations. The winter minimum sinks from 5° to 4° F. in the South, and from 22° to 40° F. in the North. In the neighborhood of the "centres of cold" the mercury not infrequently freezes. The Swedish summer, especially in the North, is a season of almost continuous daylight. The length of the summer days together with their abundant sunlight counterbalances to a very considerable extent, the shortness of the growing period. The cloudlessness of the sky in Sweden is a noted and important feature. Only 50% of the sky is covered with clouds during June, and 74% in December. By reason of this fact the heating effect of the sun's rays is relatively unimpaired.

The length of the frostless season is a matter of very great importance to vegetation. The occurrence of night frosts in Sweden during the growing period* is one of the most serious climatic difficulties with which the farmer has to contend. These frosts are not regulated by the geographical position but rather by the physical features of the country. Thus the province of Småland in southern Sweden, which is higher and much dissected by small lakes, suffers considerably from frost as do also the provinces of Uppland, Jemtland and the inner highland parts of Götaland. At Karesuando, which is situated in the extreme north—Lat. N. 68° 26′—the last spring frost occurs, on an average, on June 15th and the first autumn frost August 27th; thus there are only 72 frostless days at this point. In the neighborhood of Stockholm there are 4½ months without frost, while in Skåne early night frosts have not to be reckoned with. The damaging power of frost depends more upon the condition of the crop at the time when it occurs than upon the actual degree. In the North, vegetation does not begin until June by which time there is practically no night, and therefore no frosts. The vegetation period at this point, however, only lasts for about 100 days so that early maturing sorts are required.

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*The growing period in Sweden is regarded as beginning when spring seeding is half completed, and ending about the beginning of potato harvest.

Precipitation.

The average precipitation for all Sweden is 501 m.m (19.73"), southern Sweden obtaining considerably the greatest amount. Thus at Lund the average is 553 m.m. 9 % of which is snow; at Stockholm 482 m.m. and at Haparanda 401 m.m., 36% of which is snow.

Photo by L. H. N.

FIG. LXII.—Showing sheaves of barley put up on stakes to dry after having suffered from three weeks of almost continuous rain.

The east coast receives considerably less rain than does the West, so that dry weather in the former district during spring and early summer is not uncommon. The rainy period commonly occurs in Sweden during grain harvest, a fact which renders the satisfactory handling of crops very difficult.

The precipitation in Sweden is variable locally. Thus the monthly precipitation at any one station may vary from zero to 300 m.m. Not infrequently, droughts of several weeks' duration are followed by wet periods of about the same length.

The maximum precipitation occurs during the latter part of summer in most districts, although in Skåne a secondary maximum is reached in July or August. From the end of winter to early summer there is very little precipitation.

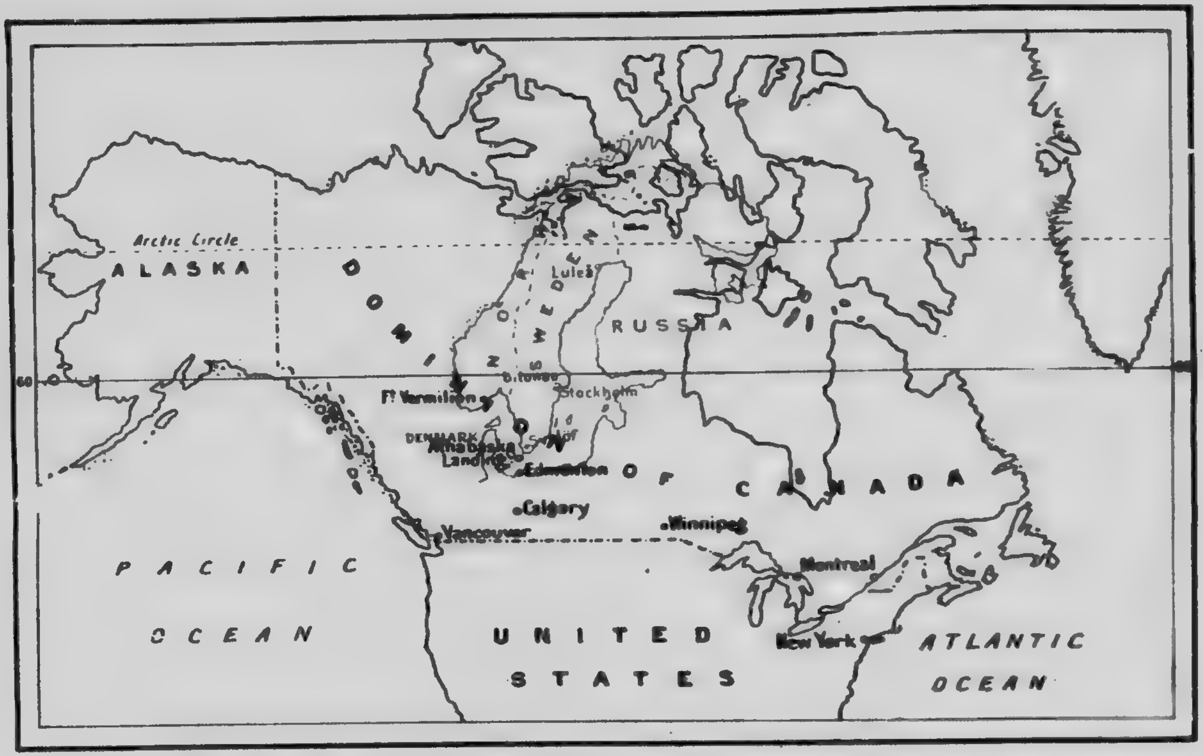

FIG. LXIII. Map showing geographical position of Sweden in relation to that of Canada.

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